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CONTENTS

	Page
A five-year record of lightning, storms and forest fires. (2 figs.) H. T. Gisborne	139
The calendar year as a time unit in drought statistics. (2 figs.) A. J. Henry	150
Solar radiation intensities within the Arctic Circle. (1 fig.) H. H. Kimball	154
Rain-gage funnels of different depths. J. Glasspoole	157
Early opening of the New York State Barge Canal. *Note.* I. R. Spencer	158
Michael Sars North Atlantic Deep-Sea Expedition. *Review.* E. B. Clarke	158
Bibliography	159
Solar Observations	160
Aerological Observations	161
Weather in the United States:	
The weather elements	163
Rivers and floods	164
Weather on the Atlantic and Pacific Oceans	165
Climatological Tables	170
Charts I–II.	

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CORRECTIONS

MONTHLY WEATHER REVIEW, Volume 37, November, 1909: Page 954, last column, the total precipitation for Fallon, Nev., recorded "7.10" inches, should be "0.71" inch.

MONTHLY WEATHER REVIEW, Volume 50, December, 1922: Page 666, the average precipitation for North Dakota, recorded "0.57" inches, should be "0.67" inch.

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A FIVE-YEAR RECORD OF LIGHTNING STORMS AND FOREST FIRES

By H. T. GISBORNE, SILVICULTURIST

[Northern Rocky Mountain Forest Experiment Station, Missoula, Mont.]

According to the records compiled by the supervisors of the national forests in the northern Rocky Mountain region, lightning has been responsible for a greater number of fires, more burned area, more damage, and more expense of suppression in this territory than all other causes of forest fires combined. Smokers, campers, brush burners, incendiarists, lumbering operations, and railroads combined start annually an average of 379 fires on these 23,000,000 acres of Federal forest land, but lightning is credited with an annual average of 824 fires during the 10-year period, 1919 to 1928. In 1926, which is accepted as one of the worst seasons for lightning fires, 311,607 acres of Federal, State, and private forest land in Idaho and Montana were burned over by fires started by lightning. The damage on this area was evaluated at $3,572,000, while the Federal Government alone spent approximately $948,000 for fire suppression.

These conditions have long been recognized as one of the major impediments to successful lumbering and forestry. As lumbering, which must depend in the future upon forestry, is one of the basic industries in this section of the country the economic importance of lightning storms is obvious. It is apparent that no industry subjected to such a chance of loss as has been indicated can operate as cheaply and efficiently as it could if the danger were fully understood and at least partially controlled.

Early in 1922 the Northern Rocky Mountain Forest Experiment Station commenced an investigation of lightning storms, working in cooperation with the Forest Service administrative organization, which had studied the occurrence of lightning-caused forest fires ever since the national forests were created. The administrative study had localized the danger both in time and by area, but it had not attempted to investigate the storms which are the causes of these fires. The research project, initiated in 1922, has been conducted for the purpose of assembling more and better information concerning the occurrence and characteristics of these storms which cause so much loss and expense.

As Morrell has pointed out (**11**) [1] the possibility of improving forest protection lies chiefly in reaching forest fires quickly and attacking them before they get large, with an adequate and properly equipped crew of men. Forest fires can be attacked with speed if they are few in number, or even when numerous, if the forest protective organization has a reasonably definite warning that such fires are probable. If warnings are available, men engaged on other work can be moved to locations more strategic for fire suppression, and additional men can be hired specifically for such an emergency. But when a single national forest of 600,000 acres, such as the Kaniksu in northern Idaho, is visited without any warning by lightning storms, that in one day start over 150 forest fires, as occurred on July 12, 1926, no forest protective organization is able to expand fast enough to cope with the situation. Under such conditions several fires are certain to be left without attention long enough for them to become so large that they spread as conflagrations through the crowns of the trees. One such crown fire often burns over more area, destroys more timber, and, after it drops to a ground fire and becomes approachable, often costs more for its suppression than a hundred or even a thousand other forest fires which are reached and extinguished before they have an opportunity to attain such momentum.

Such occurrences make very clear the importance and profitable application of warnings of lightning storms, especially if the warnings could be made available two or three days in advance, and could cover not only storm occurrences but also storm fire-starting probabilities. With such warnings action could be taken that would in nearly all cases reduce lightning fire damage and expense to a very satisfactory minimum. Even at present, with the weather predictions limited to a period of 36 hours and with no indications contained in the forecasts concerning the fire-starting characteristics of the storms, considerable progress is being made. Present investigations have contributed materially toward more accurate forecasts by obtaining more detailed records of storm occurrence. They have also found (**5**) that the types of storms which commonly start many fires can be distinguished from the types which do not start many fires. Furthermore, methods have been developed for measuring forest inflammability so that the danger of ignition and rapid spread can now be determined as a basis for administrative action (**6**).

The data herewith presented add to previously published information on lightning storms in this region largely through the increase in evidence on which the deductions are based. Some of the conclusions previously stated must now be slightly modified, but many are greatly strengthened by these 14,754 reports covering a 5-year period, as compared to the 3,800 reports for two years used as a basis for the first report. Some new aspects of the situation are also apparent in this greater volume of data.

[1] The **boldface** figures in parentheses refer to literature cited.

OCCURENCE OF STORMS

One of the outstanding discoveries resulting from this study is the knowledge that lightning storms are far more frequent in the forested sections of this region than previous records, largely obtained at low-elevation non-forest stations, had indicated. The present records, which are most complete for July and August, less complete for June and September, and fail entirely to cover the other eight months of each year, give for the region as a whole an average of 88 thunderstorm days each season, for the five years studied, as follows: 1924, 85; 1925, 95; 1926, 83; 1927, 87; and 1928, 88 days. For this same region Alexander's compilation, (2) which is quoted by most meteorological authorities, records only 10 to 30 thunderstorm days per year at individual Weather Bureau stations of the first order.[2]

FIG.I

MAP OF THUNDERSTORM OCCURRENCE.

AVERAGE NUMBER OF THUNDERSTORM DAYS EACH SUMMER, FOR GROUPS OF NATIONAL FORESTS, BASED ON RECORDS 1924-1928 INCLUSIVE. FOR NORTHERN IDAHO AND WESTERN MONTANA AS A REGION THESE DATA INDICATE AN AVERAGE OF AT LEAST 88 THUNDERSTORM DAYS PER YEAR.

This large increase in storm occurrence, indicated by the Forest Service data, is partly explained by the fact that the region has been treated as a unit, whereas Alexander's summary considers each observation station as a unit. Compilation for relatively large areas is justified, however, by the fact that fire-protection work is administered by Federal and State officials for areas seldom less than a hundred thousand acres and usually comprising many millions of acres. Weather forecasts also are usually worded to apply to large areas, half a State or more, and consequently must be based upon and should be rated according to the records of many stations. In this report relatively large areas are consequently treated as units.

Another important reason why the present summary shows more thunderstorm days than other records is the recognized more frequent occurrence of lightning storms over forested, mountainous areas, in contrast to their frequency over low elevation, valley or plains stations such as Spokane, Kalispell, Helena, Lewiston, etc., where the regular Weather Bureau observations are made.

The large number of thunderstorm days reported is also explained by the fact that the Forest Service observers used in this study consisted largely of the lookout men stationed on 270 or more high mountain tops continually scanning great areas and wide horizons for the streamers of smoke that locate forest fires. From these high points it is almost impossible for a thunderstorm to occur within 30 or 40 miles of a station without being seen or heard by the observer. It is probable that few, if any, storms escape detection during July and August, when these observatories are all occupied.

A fourth reason why the present data show more storm days than indicated by other sources of information may be that thunderstorms have been more frequent during the past few years. Such is the local opinion, but the lookout-station records do not cover a sufficient number of years to give either support or denial to this belief.

When the regional data obtained in this study are subdivided into smaller units, such as groups of national forests, a marked reduction in thunderstorm frequency is shown; yet even the totals surpass those based on observations at low-elevation stations largely outside the forests. The frequency for these small groups of forests is shown by Figure 1; and Table 1 permits comparison of these figures with those resulting from carrying the subdivision down to individual national forests.

TABLE 1.—*Relation of number of thunderstorm days to number of lightning fires per 100,000 acres for individual forests and forest groups in the northern Rocky Mountain Region*

Group and forest	Thunderstorm days, by years [1]						Fires per 100,000 acres annually
	1924	1925	1926	1927	1928	Average	
							Average number
Group I:							
Beaverhead	41	61	27	45	41	43	0.3
Deerlodge							.8
Helena	21	29	32	33	32	29	1.2
Average						[2] 56	1.0
Group II:							
Bitterroot	23	36	22	34	25	28	2.6
Lewis and Clark	15	36	32	39	19	28	.2
Missoula	23	31	28	44	39	33	1.7
Average						[2] 43	2.0
Group III:							
Blackfeet	15	20	28	35	36	27	6.8
Cabinet	9	27	24	44	40	29	4.7
Flathead	26	25	33	49	54	37	5.0
Kootenai	14	30	41	43	40	34	9.1
Lolo	20	41	34	42	44	36	3.5
Pend Oreille	20	24	26	37	40	29	5.5
Average						[2] 62	6.0
Group IV:							
Clearwater	17	35	25	28	33	28	15.1
Coeur d' Alene		33	26	50	40	37	6.9
Kansiksu	18	26	23	38	37	28	15.3
St. Joe	23	24	20	30	34	26	8.8
Average						[2] 50	11.0
Group V:							
Nezperce	29	61	47	40	41	44	3.6
Selway	30	26	44	47	55	40	7.6
Average						[2] 57	6.0

[1] Records for period June to September. June and September data are fragmentary.
[2] Group averages are higher than the averages for the forests (as explained in the text), since two or more forests may or may not report storms the same day.

These data show that on areas as large as a national forest, or a group of forests, thunderstorm frequency has been double to quadruple that indicated by W. H. Alexander's isoceraunics (ibid.) in this region. This does not imply any inaccuracy in the Weather Bureau reports,

[2] This is also true of other parts of the western third of the United States.—ED.

but it emphasizes the need for detailed records from the forested mountain areas and for special analyses of such data as a basis for forest-fire weather predictions.

In estimating the danger resulting from lightning storms one might easily be led to believe that the group of forests having the most frequent exposure to lightning as shown in Figure 1 would have the greatest number of fires per unit of area. On such a basis the Kootenai-Cabinet-Flathead-Pend Oreille-Lolo group, with 62 thunderstorm days per year, should show the greatest number of lightning fires per 100,000 acres; but Table 1 shows that this is not the case.

The fact that the number of lightning fires per unit of area is not entirely dependent upon frequency of thunderstorms, is clearly shown by this comparison of data. This lack of correlation can also be shown for the region as a whole when the records for each of the past five seasons are compared. For example, an increase of 12 per cent in the number of storm days from 85 to 95, resulted in an 80 per cent increase in the number of lightning fires, from 1924 to 1925. In 1926 the number of storm days decreased 2 per cent, but the number of fires increased 42 per cent, as compared to 1924. In 1927 there were 2 per cent more storm days, but 28 per cent more lightning fires than in 1924. In 1928 there were 3½ per cent more storm days and 14½ per cent more fires than in 1924. Hence, it appears that regardless of whether the problem is considered by groups of forests, or by years, thunderstorm frequency alone is not a dependable criterion of the probability of lightning-caused forest fires.

This information indicates that forecasts of thunderstorm days are not sufficient as a warning of lightning-fire danger. Additional information is needed for the region as a whole as to the extent and the character of the storms each day. The importance of extent of the storms is demonstrated by Table 2, which shows that as more and more stations within the region report storms in one day, the proportion of reports indicating fire-starting storms increases very rapidly. When there were few storms—only 1 to 10 stations reporting them—usually less than one station per day, or about 5 per cent of the reporting stations, stated that fires resulted. When there were widespread storms—from 201 to 304 station reports in one day— approximately 71 reports, or about 28 per cent, stated that fires resulted.

TABLE 2.—*Comparison of fire-starting storms with thunderstorm days reported, on basis of number of stations reporting storms, 1924–1928*

Stations reporting storms in one day	Thunderstorm days reported, 1924–1928		Reports of fire-starting storms	Reports of fire-starting storms per thunder storm day
Number	*Number*	*Per cent*	*Number*	*Number*
1 to 10	239	54	65	0.27
11 to 20	45	10	63	1.4
21 to 30	29	7	105	3.6
31 to 40	23	5	82	3.6
41 to 50	12	3	69	5.8
51 to 60	10	2	86	8.6
61 to 70	11	3	153	13.9
71 to 80	10	2	128	12.8
81 to 90	9	2	182	20.2
91 to 100	3	1	85	28.3
101 to 120	13	3	230	17.7
121 to 140	7	2	238	24.0
141 to 160	7	2	195	27.9
161 to 200	9	2	345	38.3
201 to 304	11	2	776	70.6
Total	438	100		

It is apparent from this compilation that the fire problem was almost negligible on 54 per cent of the thunderstorm days during the past five fire seasons, when from 1 to 10 stations reported storms each day. However, on 45 days, when from 11 to 20 stations reported storms, there was an average of at least one report that fires resulted. When from 21 to 30 stations detected storms there were nearly 4 reports each day stating that fires resulted. As one report of a fire-starting storm always means that from one to several fires were discovered, it is obvious that the occurrence of fires increases with the number of stations reporting storms, and that the need for forecasts increases in the same way. From the evidence available it appears that whenever less than 40 stations have reported storms in this region in one day no marked regional danger resulted. This might be accepted tentatively as an approximate measure of the need for regional forecasts, the greatest need beginning whenever more than 40 stations are apt to report storms in one day.

Table 3 cites the exact dates, during the 5-year period studied, when more than 40 stations reported the occurrence of lightning storms. This tabulation may be of research value in the study of conditions which have during this period caused greatest forest-fire danger in this region.

TABLE 3.—*Occurrence of dangerous thunderstorm days by number of stations reporting storms*

Number of stations reporting storms	Date of occurrence of storms				
	1924	1925	1926	1927	1928
41 to 60	July 1, 2, 3.	June 30	July 7	July 22, 24	July 5, 8.
	Aug. 1	July 21, 25	Aug. 8	Aug. 16, 20, 29	
		Aug. 13, 18, 26.	Sept. 6		
		Sept. 1, 7			
61 to 80	July 4	July 10, 11, 16.	June 29	July 28	June 25, 28.
	Aug. 14		July 1, 14, 26.	Aug. 6, 11, 21	July 29.
	Sept. 5		Aug. 26		Aug. 2, 14, 26.
81 to 100	July 5	July 12		July 2	June 2.
	Aug. 13			Aug. 23	July 12, 26, 27.
	Sept. 4				Aug. 3, 22.
101 to 150		July 17, 23, 29.	June 30	July 14, 25, 26	June 26, 27.
		Aug. 1	July 4, 5, 12	Aug. 3, 4, 7, 8, 10, 17, 25.	July 4, 13.
					Aug. 1.
151 to 200	Aug. 16	July 22, 28	July 6	Aug. 1, 2, 22, 28.	July 17, 19.
		Aug. 2	Aug. 29		Aug. 25.
201 to 250		July 24		July 31	July 16.
				Aug. 19	Aug. 4, 10, 23.
251 to 304				July 30	July 18.
				Aug. 18	Aug. 24.

The occurrence and extent of storms are also shown graphically in Figure 2, which reveals, better than a tabular statement, the relation of the days with few reports to the days of widespread occurrence of storms. It is believed that such information should serve as a basis for the study of the weather types that result in storms in the northern Rocky Mountain region, as Alexander (1) has done for the State of Washington. Such work, however, which may prove to be extremely difficult, as pointed out by Henry (8), is more a field for meteorologists. No attempt is made in the present report to analyze this phase of the problem. It is evident, however, that such analysis is basic to most accurate forecasting, and that the collection of field data by the Forest Service should be designed to supply all possible information needed by the Weather Bureau.

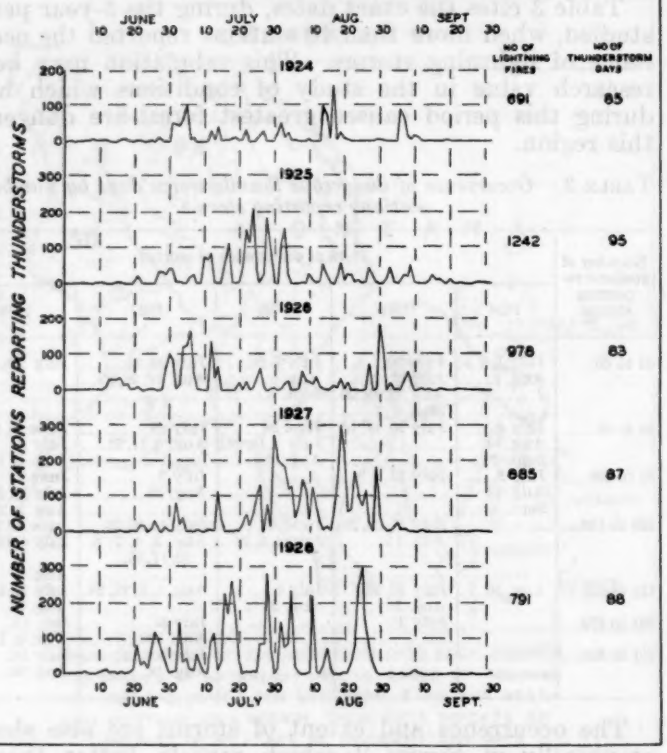
CHARACTERISTICS OF STORMS

Although it has been shown that the more widespread the occurrence of thunderstorms the greater the propor-

tion that are reported as starting fires, more information than this must be available to the forest protective organization in order to determine whether exceptional action is needed to meet the danger most efficiently. Some of the factors involved are entirely independent of the thunderstorms, and include the timber type (**13**), the prevalence of inflammable fuels, the seasonal dryness and inflammability of these fuels, and the character of the weather during the preceding days and weeks. These factors are important because green trees, unless covered with lichens, do not ignite as readily as dead trees, or snags. There are more chances of ignition where the volume of dead wood is great than where there is less dead and down wood. Early in the season most of the forest materials are usually considerably wetter, both on the surface and

FIG. II.

OCCURRENCE OF THUNDERSTORMS.



in the interior of the piece, and consequently less inflammable than during late August and early September. Likewise, if recent rains have moistened the forest fuels, or if recent hot spells have dried them, the results of a certain storm or a certain number of storms may differ greatly. All of these factors are recognized by forest protective organizations, and the importance of predictions of lightning storms is rated accordingly.

The storms themselves also vary so much that no two may be expected to produce similar results, even though both might theoretically cover equal areas of similar timber type, fuel volume, fuel inflammability, etc. Every experienced forest officer recognizes this fact and knows that there are certain characteristics which distinguish generally safe storms from prolific fire starters. For example, it is obvious that storms with more than the usual number of flashes and with a large percentage of the bolts striking the ground will start more fires than storms with only few flashes, and those largely confined to the clouds. It is also obvious that if the storm brings only a light rain of short duration more fires are apt to result than if the rain is heavy and of long duration. The present study has shown that it is possible to determine average values of these characteristics so that they may be recognized and rated specifically and uniformly by all observers.

Alexander (**1**) has stated, basing his remarks on a few reports for the State of Washington, that the percentage of flashes reported as having been confined to the clouds and the total number of flashes in each storm (the latter not always stated) do not offer a very reliable basis for a comparison of percentages as between "safe" (nonfire-causing) and dangerous (fire-causing) storms and can not at present be given much weight as determinants of the safety factor. He finds a similar lack of authority in reports of the duration of precipitation before and after the flashes. A mathematical analysis of the several thousand reports available for the northern Rocky Mountain region, however, does not support his contention. The analysis shows that the general electrical and rainfall characteristics of lightning storms can be observed by field men and that average conditions can be specified, departures from which will indicate whether the storms being observed are apt to cause more forest fires or are apt to be less troublesome, in this region.

It is highly desirable that these characteristics be determined so that inexperienced lookouts and rangers will be better able to evaluate the degree of danger in the storms that they are observing, often hours before the lightning fires send up enough smoke to be detected. These few hours of possible preparation, between studying the storm and discovering the fires, often determine the difference between full preparation to cope with many fires and lack of that preparation, with resultant large expense and damage. So long as lightning storms do vary in their ability to start fires, and so long as the official forecasts can be expected merely to indicate that storms of some sort will occur, experience has shown that fire control can at present be improved by utilizing even the most generalized estimates of the fire-starting ability of lightning storms.

The present criteria of these conditions are admittedly no better than other mathematical averages based on a large volume of data. They serve, however, to evaluate conditions which are being and must be observed. They provide usable measuring sticks, crude as they may be, for the men who must use them. They represent what is believed to be the first attempt to evolve such criteria of thunderstorm danger, and like most first attempts, they are capable of considerable improvement. A new form of report has recently been devised, which is expected to constitute one small improvement, and the observers are continually being trained to produce more complete and accurate reports. Eventually, it is hoped to improve the data still more by the use of instrumental measurements.

PRECIPITATION

When this investigation was commenced in the northern Rocky Mountain region in 1922, and when the field report form was revised in 1924, an attempt was made to obtain observations of the rainfall with each storm, most of which are single cloud affairs often only a few miles in diameter. Only about half the storm clouds pass directly over observation points, even when these are but 20 miles apart, and consequently rain-gage measurements could not be depended upon to give data on all storms. However,

lookouts at their high mountain-top station are frequently called upon by their supervising ranger to "size up" storms some distance away. Is it raining hard from the storm? How long has it been raining in Deep Creek? What drainages are getting soaked the best? These are typical questions asked of the lookout by his ranger. Therefore, on the new report form lookouts were asked for determinations of the number of minutes of rainfall ahead of the lightning, the intensity of the rainfall accompanying the lightning, and the number of minutes of precipitation after the lightning-bearing section of the storm had passed on, and, when the storm-cloud passes overhead, the actual measurements by rain gage.

Analyses of these data have shown that 92 per cent of the thunderstorms in this region are accompanied by some rain. Hence the information most urgently needed concerns the rainfall ahead of the lightning, which may moisten the fuels so that they will be too wet to ignite; and the rainfall with and following the lightning, which may extinguish any fires that do start. The analyses have failed to find any value in the reports of the intensity of the rainfall accompanying the lightning, and the original reports do not permit a determination of its duration. The other two features have been developed as follows, in Tables 4 and 5.

The outstanding feature of Table 4 is the determination based on 9,549 observations that with the average lightning storm in the northern Rocky Mountain region rain reaches the ground and moistens the fuels at any particular place for about 12 minutes before the lightning commences to flash over or to strike down to that point. This might be called the "scud rain," as it occurs ahead of the lightning-bearing portion of the cloud, approximately under the roll scud, and, as shown by these measurements, passes over very quickly.

TABLE 4.—*Record of rainfall ahead of the lightning in both wet and dry storms, 1924–1928*

Forest group [1]	Average number of minutes of rainfall by years						Basis, number of observations
	1924	1925	1926	1927	1928	All years	
Group I	7	8	9	4	12	8	662
Group II	6	12	9	16	13	13	864
Group III	12	8	21	11	10	12	4,012
Group IV	19	12	31	9	11	14	2,251
Group V	17	12	20	10	11	13	1,760
Region	13	10	21	11	11	12	9,549

[1] These groups of national forests correspond, with but two exceptions, to those used in the first report on this study, as follows: Group I, Beaverhead, Deerlodge (no data), Helena; Group II, Lewis and Clark, Missoula, Bitterroot; Group III, Blackfeet, Flathead, Cabinet, Kootenai, Lolo, Pend Oreille; Group IV, Clearwater, St. Joe, Coeur d'Alene, Kaniksu; Group V, Selway, Nezperce. The exceptions are the stopping of records from the Jefferson Forest, which was included in Group I of the first report, and the change of the Lewis and Clark from Group I to Group II, where its fire records assign it with most agreement.

TABLE 5.—*Record of rainfall following the lightning in both wet and dry storms, 1924–1928*

Forest group	Average number of minutes of rainfall by years						Basis, number of observations
	1924	1925	1926	1927	1928	All years	
Group I	42	25	42	33	44	29	651
Group II	15	34	28	38	30	31	855
Group III	46	29	70	34	33	39	4,010
Group IV	56	26	81	33	27	38	2,187
Group V	28	40	55	37	32	38	1,781
Region	40	31	64	35	33	37	9,484

The most important fact in Table 5 is the regional average for the 5-year period, showing that on the basis of 9,484 observations there is an average of 37 minutes of rainfall which may be counted on after the lightning has ceased to moisten the fuels and prevent the spread of fires caused by the lightning. This rainfall following the lightning probably is largely the so-called "secondary rain" described by Humphreys (**9**) in his analysis of the structure and behavior of thunderstorms.

In the preliminary investigation, based on the data for 1924 and 1925, averages of 11 minutes' rainfall ahead of the lightning and 33 minutes' following it were obtained. These averages were based on 2,455 reports. It is obvious from Tables 4 and 5 that the addition of data for three more seasons, raising the basis to over 9,400 reports, has not changed the first determinations materially.

Knowing the average duration of rainfall ahead of the lightning, and following it, the important question immediately arises: Do the storms that started fires show any appreciable differences in amount of rainfall when compared to storms that did not result in fires? The available data on this phase of the problem are shown in Tables 6 and 7. The number of reports used as a basis in these tables is less than shown in Tables 4 and 5, because many reports failed to state specifically whether or not the storm started fires.

TABLE 6.—*Record of number of minutes of rainfall ahead of the lightning in fire-starting as contrasted with nonfire-starting storms, 1924–1928*

Year	Nonfire-starting storms		Fire-starting storms	
	Average rainfall	Basis, reports	Average rainfall	Basis, reports
	Minutes	*Number*	*Minutes*	*Number*
1924	16	391	9	253
1925	9	718	8	426
1926	29	670	13	334
1927	12	1,622	7	575
1928	11	734	8	532
Total and average	14.6	4,135	8.7	2,120

This table shows an average difference of 5.9 minutes in the duration of the scud rain ahead of the lightning is dangerous as compared to safe storms. Although this is a small absolute quantity, it is proportionately very large (68 per cent of the 8.7-minute average); and it is also consistently true that each year the nonfire-starting storms have a greater average rain than the fire-starting storms. This being true, and considering the basis of 6,253 reports over a 5-year period, it seems entirely safe to conclude that there is an appreciable and a significant difference in the amount of the rainfall ahead of the lightning in safe and dangerous storms.

TABLE 7.—*Record of number of minutes rainfall following the lightning in fire-starting as contrasted with nonfire-starting storms, 1924–1928*

Year	Nonfire-starting storms		Fire-starting storms	
	Average rainfall	Basis, reports	Average rainfall	Basis, reports
	Minutes	*Number*	*Minutes*	*Number*
1924	50	414	34	257
1925	32	736	27	436
1926	74	695	44	338
1927	38	1,581	32	578
1928	37	730	23	520
Total and average	44.0	4,156	30.8	2,138

In Tables 7, again, for the secondary rain following the lightning, the data show 13.2 minutes, or 43 per cent longer rainfall for storms which did not start fires than for dangerous storms. Here, also, a large number of reports covering a 5-year period are used as a basis. And again the data are consistent; no average for any one year in the fire-starting storms is greater than the general average for all nonfire-starting storms, and no single average for the safe storms is less than the general average for the dangerous storms.

Tables 6 and 7 seem to demonstrate rather conclusively that fire-starting storms in this region are generally characterized by less rainfall, both ahead of and following the lightning, than safe storms which are characterized by precipitation over longer periods.

The principal purpose served by these averages in Tables 4, 5, 6, and 7 is the approximate determination of a condition which varies within wide limits, so that definite averages can be stated above which departures generally indicate less than the usual need for fire control, and below which departures indicate more need for action. The averages given, however, include both dry and wet storms. It is therefore possible to eliminate the dry storms and by considering only those which brought some rainfall, either ahead of or following the lightning, to determine the duration of the rainfall only for the wet storms. Naturally, this duration will be appreciably greater than the average determined on the basis of both wet and dry storms.

Of 7,093 reports of both classes of storms only 48 per cent state no rain ahead of the lightning. The remaining 52 per cent state an average of 25 minutes of rain ahead of the lightning. As would be expected, this is approximately double the average for both wet and dry storms. On this basis it is evident that the average storm reported as having rain ahead of the lightning may be expected to bring about 25 minutes of precipitation.

The records show that there is a smaller proportion of storms that are dry following the lightning than of those that are dry ahead of the lightning. Only 33 per cent of a total of 6,983 reports stated that no rain fell after the lightning had passed on. The other 67 per cent show an average rainfall of 58 minutes' duration. This time interval, which can be used as an additional criterion of degree of danger in this region, indicates that the "secondary rain" described by Humphreys occurs in about two-thirds of all the thunderstorms in this region, and lasts for about one hour.

Further examination of the data on rainfall ahead of the lightning, by subdivisions of the region, shows that, for each of the five groups of forests previously described, the conclusion holds true that there is less rainfall ahead of the lightning with fire-starting storms than with safe storms. Table 8 shows the averages and the number of reports on which they are based, for each of these groups.

TABLE 8.—*Record of number of minutes' rainfall ahead of lightning in fire-starting as compared with nonfire-starting storms, by forest groups, 1924–1928*

Forest group	Nonfire-starting storms		Fire-starting storms	
	Average rainfall	Reports	Average rainfall	Reports
	Minutes	*Number*	*Minutes*	*Number*
Group I	8.8	511	2.8	33
Group II	12.8	545	6.7	97
Group III	15.4	1,637	6.8	803
Group IV	18.4	749	9.6	687
Group V	14.5	693	11.3	500
Region	14.6	[1] 4,135	8.7	[1] 2,120

[1] Reports used for Table 8 are the same as used for Table 6.

In the same way the data on rainfall following the lightning (Table 9) show that in each of the five groups of forests there was less rain after the lightning in fire-starting storms than in safe storms.

TABLE 9.—*Record of number of minutes rainfall following the lightning in fire-starting as compared with nonfire-starting storms by forest groups, 1924–1928*

Forest group	Nonfire-starting storms		Fire-starting storms	
	Average rainfall	Reports	Average rainfall	Reports
	Minutes	*Number*	*Minutes*	*Number*
Group I	36.0	507	23.2	36
Group II	34.2	548	18.4	99
Group III	47.0	1,662	31.8	802
Group IV	51.0	753	28.4	687
Group V	42.9	686	35.2	514
Region	44.0	[1] 4,156	30.8	[1] 2,138

[1] The reports used for Table 9 are the same as used for Table 7.

No attempt is made in this report to determine statistically the probable error of these averages, or the significance of differences between the averages for the various groups. Apparently the actual use of the criteria by lookouts and others will not be affected at present if the regional averages are used by all forests regardless of their group, because in all cases departures from the regional averages are similarly significant in each of the groups.

DRY STORMS

Although most lightning storms bring some rain with them, so-called "dry lightning storms" are often credited with starting a large proportion of forest fires in this region. It is entirely reasonable to believe that such storms are decidedly apt to start fires if their bolts are numerous, and if they reach dry fuels on the ground. The records show, however, that only 6 to 10 of every 100 lightning storms recorded in this investigation (14,754 reports) were dry, delivering no rain whatever to the ground beneath the storm cloud. The reports (8,408) which were definite with regard to both the rainfall and the fire-starting character of the storms, showed that only 33 per cent of the dry storms were fire starters. Hence, only 2 or 3 storms out of 100 are both dry and fire starters.

The occurrence of these dry lightning storms in this region is interesting in two respects. First, these reports prove the occurrence of a type of thunderstorm not included by some meteorological definitions; and, second, the so-called dry storm is popularly credited in this region as being the most dangerous fire starter. During the 5-year period covered by this study, the tabulation of 1,238 reports of lightning storms with no rain before, with, or following the lightinng, out of a total of 14,754 reports, should remove all doubt as to dry storm occurrences. And such conditions depart decidedly from Clayton's descriptions (**4**) and disagree with Moore's definition of a thunderstorm (**10**). This definition reads: "The thunderstorm, so familiar to everyone, may be defined as a local rain accompanied by lightning, thunder, gusts of wind, and frequently hail." Humphrey's definition (Op. cit.), "A thunderstorm, as its name implies, is a storm characterized by thunder and lightning . . .," appears to apply more conclusively in this region.

Of the reports of absolutely dry storms, stating definitely whether or not fires resulted, 68 per cent showed that no fires resulted. Of the definite reports of wet storms,

on the other hand, 66 per cent stated that no fires resulted. This close similarity refutes the popular conception that dry storms as a class are more dangerous than wet storms. It also raises a question concerning other data, previously presented, which show for the majority of lightning storms that with less rain there are more fires, and with more rain less fires.

The reason for this apparent anomaly undoubtedly lies in the nature of dry thunderstorms, in which the flashes are generally few, and nearly all confined to the clouds. The meteorological reasons for these peculiarities in activity may lie in the well-supported theories (9) that violent, turbulent action of large masses of drops of water forming the cloud are most favorable to the generation of lightning, and that practically continuous sheets of water (rain drops) and streaks of highly ionized air form favorable paths for the bolts. Hence, clouds too small to precipitate moisture enough to reach the earth (as in dry storms) may often be large enough and active enough to generate a few flashes which will be almost entirely confined to the clouds. Large, active, and rain-producing clouds, on the other hand, may be expected to produce a greater number of flashes, with a greater number of bolts striking the ground.

LIGHTNING

That the proportion of the lightning flashes confined to the clouds has an appreciable effect upon the starting of fires is shown by the analysis of the records bearing on this feature. Table 10 shows this for the region as a whole by years. The safe storms consistently show a higher percentage of lightning confined to the clouds than do the dangerous storms.

The significance of data concerning percentage of lightning confined to the clouds, and striking the ground, obviously would be increased if the total number of flashes per unit of time, or the total number as a storm passed over a certain spot, were known. It has been found difficult, however, to obtain such counts as accurately as desired. Consequently, this aspect of the problem can not be examined at present. Work is being done, nevertheless, to obtain this information for later use.

TABLE 10.—*Percentage of lightning flashes confined to the clouds*

Year	Nonfire-starting storms		Fire-starting storms	
	Flashes, confined to the clouds	Basis, number of reports	Flashes, confined to the clouds	Basis, number of reports
	Average per cent		*Average per cent*	
1924	73	468	61	318
1925	68	835	55	565
1926	71	854	55	442
1927	80	2,470	58	736
1928	76	860	53	670
Average and total	76	5,487	56	2,731

This summary for the region, based on 8,218 observations, shows 20 per cent more lightning confined to the clouds in safe storms than in dangerous ones. From these data it is possible to establish indexes of the degree of danger as influenced by this factor. It is apparent that as a general rule if less than half of the lightning is confined to the clouds the storm is of the fire-starting type, whereas if more than three-fourths of the lightning stays in the clouds the storm is of the safe type. Intermediate amounts probably should be considered as more dangerous than safe.

A sorting of these data by groups of forests, rather than by years, also shows uniformly that the safe storms have more of their lightning confined to the clouds than do the dangerous storms. Whereas the first report on this investigation, which covered only the data for 1924 and 1925, indicated that there might be a slightly significant difference between groups of forests in the percentage of lightning confined to the clouds, the present and more comprehensive data show rather uniform percentages. As is evident from Table 11, no group average varies more than 9 per cent from the average of any other group, and none departs more than 6 per cent from the regional averages. Apparently, the criteria of degree of danger according to the amount of lightning confined to the clouds, as established on the basis of the regional data, are applicable in each of the subdivisions.

TABLE 11.—*Percentage of lightning flashes confined to the clouds in safe and dangerous storms*

Forest group	Nonfire-starting storms		Fire-starting storms	
	Flashes, confined to the clouds	Basis, number of reports	Flashes, confined to the clouds	Basis, number of reports
	Average per cent		*Average per cent*	
Group I	72	568	50	38
Group II	76	726	55	133
Group III	77	2,235	58	1,016
Group IV	78	975	53	865
Group V	72	983	59	679
Average and total	76	5,487	56	2,731

OTHER CHARACTERISTICS

In addition to the rainfall, or lack of it, and in addition to the character of the lightning, there are other features of lightning storms which affect successful forest-fire control. These include the time of day when the storms are first seen, the prevalence of storms after dark, the passage directly over the lookout stations, and the common direction of storm movement.

When lightning storms are recognized as such during the forenoon hours, it is generally possible for a ranger or his assistant to get in touch by telephone with his various employees, including trail crews, before the resultant fires have begun to be discovered by the lookouts. This is, therefore, one possibility of obtaining greater speed in fire control.

Table 12 shows the percentage of reports by years and by groups of forests, stating that the storms were first seen during the forenoon hours.

TABLE 12.—*Storms first seen in the morning, by forest groups*

Year	Group I	Group II	Group III	Group IV	Group V	Regional average
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1924	24	13	18	19	35	23
1925	17	13	25	27	25	24
1926	25	31	31	32	44	34
1927	16	17	20	23	27	22
1928	22	20	23	28	30	25
Average	20	20	24	26	31	25

The outstanding indication from this compilation, based on over 14,000 observations, is that about one storm out of four is first seen before noon, and thereby permits fire-control action early in the day if the lookout immediately reports storms to his ranger.

The consistently high percentages shown by Table 12 for all groups of forests during 1926 may be of meteorological significance, and it is hoped that the study of such phases will appeal to some meteorologists. It should be mentioned here that all of the reports, for the entire day, have been specially sorted and tabulated on an hourly basis at the request of the Spokane office of the United States Weather Bureau, so that the development of storms throughout this region may be studied intensively in relation to the twice daily synoptic weather maps. From this study it is hoped to derive considerable information of value for increasing the accuracy of future forecasts and for localizing them.

The prevalence of storms at midnight has been determined merely as an approximation of the number of storms occurring during the middle of the night. The data show the following percentages of the total number of observations, which stated that the lightning storms were occurring at that hour: 1924, 5 per cent; 1925, 3.5 per cent; 1926, 7 per cent; 1927, 4 per cent; and 1928, 4.5 per cent; average for the 5-year period, 4 per cent. The importance of storms occurring during the hours of darkness lies in the inability of the lookouts to detect the resultant fires, unless the flames are so located as to be directly visible. In the meantime, and before men can reach the spot and commence suppression, the fire may have several hours in which to spread. Furthermore, since it is very difficult at night for the lookouts to make azimuth readings of lightning bolts striking, the effects of storms at night can not be accounted for so accurately. With some 4 per cent of the storms occurring at midnight, it is obvious that an appreciable number of storms are in action during the night when close observation is extremely difficult or impossible. Compilations of future data will be made to develop more specific information on this phase of the problem.

The passage of lightning storms directly over a lookout station is important in several ways. Frequently the resultant fires will be close to the station and can be attacked immediately. On the other hand it often happens that a storm cloud whose path includes the mountain top lookout station will envelop the station and reduce visibility from that point to such a degree that the direction of lightning flashes can not be discerned and resultant fires only a half mile away are invisible until the cloud has moved by.

The reports by the lookouts show the following percentages of cases in which the storms passed directly over one or more of the lookout stations: 1924, 48 per cent; 1925, 47 per cent; 1926, 47 per cent; 1927, 42 per cent; 1928, 39 per cent. This means that in about 4 or 5 of 10 observations a storm will pass directly over some lookout station and consequently that many reports on storms will be, and frequently must be, made by stations at some distance from the storm. Hence, no method of observation should be used which depends upon the storm passing directly over the observation station.

Probably the best method of determining whether or not storms are apt to start fires near lookout stations, and the likelihood of such clouds reducing visibility from that point, will be to examine the data separately for each lookout. It is believed, however, that there is not yet a sufficient volume of reports for individual stations to warrant such a detailed sorting and tabulation. Such an analysis is planned for some future date.

One feature of storm occurrence upon which we have no dependable data is the altitudinal range of the clouds, which might influence or even control zones of lightning danger as Ward (**14**) has described them on the authority of F. G. Plummer (**12**). These zones are specifically defined as being areas of lightning danger, but it is implied that high mountain tops may be above the clouds and so in a zone of safety. To investigate the occurrence of lightning-fire zones the locations of several thousand lightning fires in the northern Rocky Mountain region have been plotted on maps by H. R. Flint, in charge of fire control of the Forest Service in this region. Although these maps show conditions for more than 10 years, there is not any consistent evidence that lightning fires occur in zones limited altitudinally in any way, except by the absence of inflammable material, and by the wetness of these fuels. There is, instead, a most baffling scattering of these fires which renders the problem of successful control all the more difficult. It is recognized that these maps show merely the occurrence of lightning-caused fires and, therefore, not all points struck by lightning, but this appears to be the best information available.

Flint is also making a study of the occurrence of lightning fires in relation to mineral-bearing areas in an effort to determine whether or not geological formations have any appreciable effect upon lightning strokes and fires. The Forest Service fire records and the geologic maps for the Coeur d'Alene region are being used for this work.

Another characteristic of lightning storms that may have meteorological significance which will be of value in prediction is the common direction of storm movement in different parts of the northern Rocky Mountain region. There are 14,595 reports which serve for determining this characteristic of storms for this region. Tables 13 and 14 show the results of the analysis by years and by groups of forests.

TABLE 13.—*Direction of movement of storms, by years, toward the directions given*

Movement of storm	1924 reports		1925 reports		1926 reports	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
North	196	16	333	13	267	12
Northeast	456	36	891	36	671	31
East	371	29	762	31	651	30
Southeast	80	6	215	9	199	9
South	36	3	70	3	89	4
Southwest	36	3	64	3	91	4
West	31	3	52	2	73	4
Northwest	40	3	87	3	89	4
Stationary or revolving	18	1	7	0	34	2
Total	1,264	100	2,481	100	2,164	100

Movement of storm	1927 reports		1928 reports		Total reports	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
North	461	11	451	10	1,708	12
Northeast	1,207	28	1,233	28	4,458	31
East	1,383	32	1,403	32	4,570	31
Southeast	425	12	714	16	1,731	12
South	248	6	259	6	702	5
Southwest	140	3	134	3	465	3
West	107	3	79	2	342	2
Northwest	158	4	100	2	474	3
Stationary or revolving	47	1	39	1	145	1
Total	4,274	100	4,412	100	14,595	100

Table 13 clearly shows the marked tendency of lightning storms to travel toward the northeast and east in this region. Only 12 per cent of the reports show a movement toward the north, and the same proportion toward the southeast, all other directions being credited with only 5 per cent or less. The changes from year to year during the period studied do not appear to be significant.

Table 14 indicates that there are no marked differences in direction of storm movement between the various groups of forests. While Group I, in the northeastern part of the region and largely east of the Continental Di-

vide, shows the highest percentage of movement toward the east, Group V, in the southwestern part of the region, shows the greatest movement toward the north and northeast. The significance, if any, of these differences is a problem for the meteorologists. Perhaps these data serve as an index of the probability of summer rain, from each cardinal direction, but the practical application of such information in fire control is doubtful.

TABLE 14.—*Direction of movement of storms, by forest groups (movement toward the directions given)*

Movement of storm	Group I reports		Group II reports		Group III reports	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
North	55	7	146	11	694	11
Northeast	281	34	396	31	1,514	25
East	339	42	503	39	1,918	31
Southeast	57	7	115	9	975	16
South	22	3	41	3	391	6
Southwest	17	2	26	2	231	4
West	14	2	37	3	148	2
Northwest	24	3	33	2	217	4
Stationary or revolving	2	0	2	0	57	1
Total	811	100	1,299	100	6,145	100

Movement of storm	Group IV reports		Group V reports		Region reports	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
North	424	12	389	13	1,708	12
Northeast	1,003	29	1,264	43	4,458	31
East	1,006	29	804	28	4,570	31
Southeast	388	11	196	7	1,731	12
South	198	6	50	2	702	5
Southwest	137	4	54	2	465	3
West	102	3	41	1	342	2
Northwest	121	4	79	3	474	3
Stationary or revolving	57	2	27	1	145	1
Total	3,436	100	2,904	100	14,595	100

One other feature of the movement of lightning storms has a possible bearing on fire control. This concerns the possible tendency of storms to follow more or less regular paths, perhaps according to the topography or the local presence or absence of thunderstorm-breeding conditions, as Brooks (**3**) and Hallenbeck (**7**) have described them.

Naturally, the determination of localities most frequently exposed to lightning storms is of great importance in deciding upon the forest protection facilities that should be provided for different areas. Field observers in this region are strongly of the opinion that certain topographic features and localities are common centers of formation of storms and that there are certain paths of movement which are followed much more frequently than other paths. The present records covering all subdivisions of the region have not been exhaustively examined, but detailed analyses have been made of several restricted areas, comprising up to about a million acres, and for some of the most dangerous days thunderstorm reports for the entire region have been plotted on maps. These minor studies have failed to find any marked topographic paths along which thunderstorms may commonly be expected to travel. It is planned to investigate these conditions more intensively a few years hence, after the volume of records from each station has increased materially.

LIGHTNING-CAUSED FIRES

The number of lightning fires per unit of area is a basic consideration for forest-protective agencies. This figure is not the same for different parts of the United States, nor even for different parts of the northern Rocky Mountain region, being governed largely, as has been seen, by the number and characteristics of storms.

When storms are accompanied by more rain than the average and when they have more than the usual amount of lightning confined to the clouds, a smaller proportion of them cause fires. When they are accompanied by less rain than the average, however, and have most of the lightning striking the earth a larger proportion is dangerous. Though the seasonal wetness or dryness of the forest fuels undoubtedly influences the probability that a storm of certain character may start fires, the two conditions, occurrence of storms (as indicated by number of thunderstorm days) and the characteristics of storms (as shown by percentage of storms starting fires) are essentially indicative of the lightning fire hazard per unit of area in a given timber type in this region.

The relationship between storm occurrence, characteristics, and the number of resultant fires can be expressed as a simple formula which, when applied to the data for each of the five regional subdivisions, serves to compute the average number of lightning fires per unit of area with a maximum error of one and one-half fires per 100,000 acres. The formula used was $\frac{10b}{a}=c$. The data are shown in Table 15.

TABLE 15.—*Thunderstorm occurrence, danger and fires*

Forest	Average thunderstorm days per year (a)	Reports showing storms starting fire (b)	Actual lightning fires per 100,000 acres per year	Computed lightning fires per 100,000 acres per year (c)
	Number	*Per cent*	*Number*	*Number*
Group I	56	6	1	1
Group II	43	15	2	3½
Group III	62	31	6	5
Group IV	50	47	11	9½
Group V	57	41	6	7
Region	87	34	5	4

The data in Table 15 show again that occurrence of storms is not, by itself, a satisfactory index of the degree of danger of lightning fires. Before the degree of lightning-fire danger can be estimated satisfactorily fire weather forecasts must consider other factors—the characteristics of the storms and probably the seasonal and current moisture content and inflammability of the forest materials. As has been shown, these conditions can be observed and measured with sufficient accuracy to improve very greatly the knowledge of probable danger. The combination of conditions resulting in the highest degree of local danger consists of numerous storms of the fire-starting type covering a small and often inaccessible area on which the fuels are extremely dry.

Table 15 also shows the relative danger of lightning storms for the region and for each of its subdivisions. For the region as a whole about 34 storms out of 100 are dangerous, while for the subdivisions this figure varies from 6 to 47. The actual average number of fires per unit of area show that the importance of the lightning problem varies more nearly with the percentages of storms starting fires (i. e., storm characteristics) than with mere storm occurrence.

There is one other feature of lightning fires which is of great importance in successful fire control. This is the period of time which commonly elapses between the first sighting of a storm by a lookout and the discovery from the same station of each of the resultant fires. It is obvious that if a storm is sighted some hours before the fires it started are discovered, such a period offers greater

opportunity for the lookout to inform his ranger of the path of the storm, the probability of fires, and even the probable location of fires, according to his observations of where lightning is striking. Likewise, a long period offers the ranger more time to request an air patrol of his district, and more time to communicate with his fire guards, smoke chasers, patrolmen, and road, trail, and telephone construction or maintenance crews, so that they may move to more strategic locations if the ranger desires. All this will assist greatly in catching fires while small—the first essential in effective fire control. Prompt and well-advised action is therefore required, especially when not enough men are regularly employed to attack an exceptional number of fires efficiently. Speed and dependable information are even more important in the region under study than elsewhere, because here are several national forests with an average of only 16 to 18 miles of road and trail per township of 23,040 acres, and measured travel off the trail is at the seemingly low average rate of only 1 mile per hour. Under such conditions it is extremely desirable to grasp all opportunities for moving men as early as possible to locations from which a minimum of travel will be required to reach the fires.

As an index of the time available for reporting on the important features of lightning storms before the fires are detected, 4,149 reports state definitely the time when the storm was first seen and the hour and minute when the fires were discovered. Of these 2,338 reports show the time between first sighting the storm and the discovery of the first fire, 959 reports state the time before discovering the second fire, 538 reports cover a third fire, and 314 give data for a fourth. The results have been arranged to represent conditions for an average lookout station and show the probability of a first discovery of a fire within definite periods of time after sighting the storm, or if two fires are discovered the probable elapsed time for the second discovery and similarly for third and fourth fires. The records show that occasionally a single lookout has reported 10 or 12 fires caused by one lightning storm, but the majority of the reports show far less than this.

When the cumulative percentage of discoveries were plotted by hourly periods (hours following the first sighting of the storm) and the data were curved, the values given in Table 16 were obtained.

TABLE 16.—*Percentages of storm reports showing various intervals between sighting of storm and discovery of subsequent fires*

Hours after first sighting storm	First fire	Second fire	Third fire	Fourth fire
	Per cent	*Per cent*	*Per cent*	*Per cent*
0 to 1	20	16	12	8
1 to 2	16	12	12	13
2 to 3	11	11	10	8
3 to 4	8	9	9	6
4 to 5	5	6	5	4
5 to 6	4	4	5	4
6 to 12	12	14	15	16
12 to 18	7	8	8	11
18 to 24	5	6	6	7
24 to 48	5	6	8	9
Over 48	7	8	10	14
Total	100	100	100	100

Table 16 shows that the period of time between first sighting the storm and the discovery of fire lengthens very appreciably with each subsequent fire. For example, about half the first fires are discovered within three hours after the lookout first sees the storm. In other words, to be amply prepared to reach and hold as many as half of the first fires, only three hours is available for presuppression action after the storms are sighted. Four hours can be allowed for equal preparation for second fires, five hours for third fires, and over six hours are available for the majority of the fourth fires. The importance of these determinations lies in the fact that regardless of whether or not lightning storms have been previously predicted by the Weather Bureau, there is, after the storm actually appears, a very appreciable period of time available to mobilize men and otherwise prepare for the probable fires. Obviously, in regions like northern Idaho, where 4 or 5 storms out of 10 usually start fires, such an opportunity for preparation is decidedly desirable.

Another important fact indicated in Table 16 is the considerable number of discoveries of fire made only after a lapse of 48 hours. For the region as a whole, for the 5-year period, 333 reports show this so-called "hang-over" condition. These reports comprise 8 per cent of the reports studied, and it is worth mentioning here that in 160 instances in these reports these hang-overs were first discoveries. Consequently, it is obvious that even though a lightning storm passes by and no fires are discovered within the following two days, there is still an appreciable chance that fires, were started and will show up later on.

TABLE 17.—*Percentage of fires discovered 48 hours or more after the storm was first seen*

Year	First fire	Second fire	Third fire	Fourth fire
	Per cent	*Per cent*	*Per cent*	*Per cent*
1924	8	3	1	4
1925	10	15	20.5	23
1926	6.5	12	15	20
1927	6	5	8	15
1928	5	4	4	6
Average	7	8	10	14

Table 17 shows that since 1925 there has been a consistent reduction in the percentage of discoveries made more than 48 hours after the storm appeared. Whether this has been brought about by the establishment of more lookout stations directly surveying more area, the removal of old stations to new and better locations, or by better trained and more conscientious personnel can not be determined from these reports. A marked and very desirable improvement in fire control is evident, nevertheless.

When the speed of detection is compared for the five subdivisions of this region the most outstanding fact is that the Beaverhead-Helena group of forests, which has very few lookout stations at high elevations, shows a consistently longer period of time between sighting the storm and making the first discovery of a fire. For example, four hours after the storm appears only 50 per cent of the first discoveries have been made on the Beaverhead-Helena group, while 60 per cent have been made on the north Idaho forests comprising Group IV. Twelve hours after the storm is first seen the eastern Montana forests have made only 66 per cent of their first discoveries, while Group IV has made 77 per cent and Group V 79 per cent. At the 24-hour mark the Beaverhead-Helena have only 74 per cent to their credit, while Groups IV and V have 89 per cent and 90 per cent, respectively.

In this region there are two other observations which have also been found of immediate value and usefulness. The first is the measurement of azimuths or compass bearings on points struck by lightning and the recording of these measurements so that these spots can be watched very carefully for at least 48 hours to come. (A special

form is provided for noting such observations.) As a result of such action many fires may be discovered as soon as the first wisp of smoke rises from the spot and hours before the usual smoke column begins to be clearly visible. The second observation is whether the spots struck by lightning are well soaked, lightly sprinkled, or entirely unmoistened by the storm. Experience has shown that even with storms bringing heavy rainfall lightning may strike one or more places near the edge or even outside the area wetted. Naturally, if the fuel types are similar, a bolt falling outside the rain area will have a better chance of starting a fire than one at a spot which is thoroughly soaked by rainfall. But of even more importance is the fact that if fires result in both cases the one outside the rain area is much more in need of immediate attention than the one that is surrounded by wetter fuels, and the former should be attacked first if there must be a choice. Usually the lookout is the only member of the forest protective organization who is in a position to make this important fact known to the ranger, central dispatcher, or whomsoever may be responsible for sending men to these fires.

SUMMARY

Because lightning is the most important single cause of forest fires in the northern Rocky Mountain region a special study has been made by the Forest Service of the occurrence and characteristics of lightning storms in that region. This study utilized the data obtained from fire lookouts stationed on approximately 200 mountain tops, so distributed that very few storms could occur during the summer months without being reported by the lookouts. A special form was used for obtaining the desired information, which is now summarized for the 5-year period 1924 to 1928, inclusive.

The results show that about 34 storms out of 100 have caused forest fires and that there are from two to four times more thunderstorm days per year in this region than had been previously estimated. It is found, however, that the danger of forest fires caused by lightning is not in proportion to the number of thunderstorm days but varies more with the characteristics of the storms. The greatest number of fires and the greatest proportion of reports of fire-starting storms were found on 20 days, which constitute only 4 per cent of the total number of thunderstorm days. Records are included so that these so-called easy and bad days may be studied in relation to the daily weather maps.

An analysis of the 14,754 lookout storm reports available shows that there are recognizable differences between the types of storm that usually start fires and the types that are generally safe. These differences are found to lie in the duration of the rainfall ahead of and following the lightning, together with the electrical activity of the storm and the percentage of lightning flashes confined to the clouds or striking to the earth. Average duration of rainfall, and average percentage of lightning flashes striking to the ground, have been determined separately for the safe and for the dangerous storms. It is pointed out that by observing these characteristics it is often possible for the lookouts to classify a storm as either generally safe or generally dangerous hours before any of the resultant fires produce enough smoke to permit discovery. Such advance information permits the forest protective agency to move men into or near the danger area so that the fires can be reached more quickly and be extinguished more cheaply while yet small.

It is found that the so-called dry storm (having no rainfall reaching the ground) occurs in only 6 to 10 cases out of 100. Of all these dry storms only one-third started fires, whereas one-third of the wet storms were also dangerous. The reasons for this anomaly are believed to be in the lesser number of lightning flashes in dry storms together with a lesser proportion of these flashes reaching the ground. Naturally, no fires can be started by a dry storm if all of the lightning is confined to the clouds.

* * * * *

From these facts, developed by the analysis of the reports on lightning storms, it is obvious that there are four observations which forest-fire lookouts can make which are of immediate value to the forest ranger directly in charge of fire control: (1) The occurrence of storms; (2) their paths: (3) the accompanying precipitation, if any; and (4) the percentages of lightning confined to the clouds and striking the ground. Always, the flash of lightning or the rumble of thunder will be the best assurance of thunderstorm occurrence, but usually the formation of cumulus clouds of the thunderstorm type and size is sufficiently definite, especially if storms have been predicted by the Weather Bureau. As the storm develops and the lookout is able to estimate its probable path he may be able to determine whether the particular ranger district which includes the lookout station is apt to be affected. If it is, then some prominent topographic feature will serve to time the duration of rainfall and to estimate the character of the lightning as the storm passes over that point. Such information, obtained by a careful observer, is now recognized as an excellent basis for fire control action in the northern Rocky Mountain region.

Some other characteristics of storms determined by this study include the finding that 25 per cent of the storms are first seen before noon; about 4 per cent of the storms are active during the middle of the night; only 4 or 5 observations out of 10 report the storm as passing directly over the observation station, thereby indicating the local character of lightning storms in this region; 62 per cent of all thunderstorms in the northern Rocky Mountain region move toward the northeast and east, while 86 per cent are found to travel in a direction between north and southeast; no common topographic paths of travel have as yet been discernible.

This study is to be continued, using an improved report form to obtain additional detail of information as well as to record if possible any increase or decrease in the occurrence of lightning storms over a longer period.

LITERATURE CITED

(1) ALEXANDER, G. W.
1927. Lightning Storms and Forest Fires in the State of Washington. U. S. Mo. Weather Rev. 55: 122–129.

(2) ALEXANDER, WM. H.
1924. The Distribution of Thunderstorms in the United States, U. S. Mo. Weather Rev. 52: 343–348.

(3) BROOKS, CHARLES F.
1922. The Local or Heat Thunderstorm. U. S. Mo. Weather Rev. 50: 281–284.

(4) CLAYTON, H. H.
1923. World Weather., illus. New York.

(5). GISBORNE, H. T.
1926. Lightning and Forest Fires in the Northern Rocky Mountain Region. U. S. Mo. Weather Rev. 54: 281–286.

(6) ———
1928. Measuring Forest Fire Danger in Northern Idaho. U. S. Dept. Agr., Forest Service. Misc. Pub. 29, 63 p., illus.

(7) HALLENBECK, CLEVE
1922. The Topographic Thunderstorm. U.S. Mo. Weather Rev. 50: 284–287.

(8) HENRY, A. J.
1927. Can Thunderstorms be Classified? U. S. Mo. Weather Rev. 55: 118.
(9) HUMPHREYS, W. J.
1920. Physics of the Air. 665 p., illus. Philadelphia.
(10) MOORE, W. L.
1910. Descriptive Meteorologv. 344 p., illus. New York.
(11) MORRELL, FRED
1929. Forest Protection Needs in the Inland Empire. Jour. Forestry 27: 143–147.
(12) PLUMMER, F. G.
1912. Lightning in Relation to Forest fires. U. S. Dept. Agr., Forest Serv. Bul. 111, 39 p., illus.
(13) SHOW, S. B., and KOTOK, E. I.
1929. Cover Type and Fire Control in the National Forests of Northern California. U. S. Dept. Agr., Forest Serv. Bul. 1495, 35 p., illus.
(14) WARD, R. DEC.
1925. The Climates of the United States. 518 p., illus. New York.

THE CALENDAR YEAR AS A TIME UNIT IN DROUGHT STATISTICS[1]

By ALFRED J. HENRY

[Weather Bureau, Washington, March 17, 1931]

As almost everyone knows, the year is generally considered as being too long a unit for use in compiling drought statistics. While admitting the general soundness of that view, it is believed that the disadvantages of the calendar year have been somewhat exaggerated. The case of Arkansas in 1930, when the percentage of the normal precipitation received was 96 per cent, will naturally come to mind. In this case two of the months, January and May, had 223 and 200 per cent of the normal, respectively, and the real lack of rain that caused the failure of the cotton crop was confined to the months of June and July, with 22 and 19 per cent, respectively. Most persons fail to consider that the very great rainfall of January and May was in itself quite abnormal and not likely to again happen in the next 50 years.

The reason why a shorter period than the year has not heretofore been used in compiling drought statistics is most likely because of the overlapping of drought periods from one month to the next and the fact that its ending rarely occurs at the end of a month; thus it would be necessary to make a special compilation in order to fix the definite limits of the duration of droughts. This has not been done, and to do it now for previous droughts is prohibitive on account of the labor involved.

The object of the present compilation was therefore to ascertain to what extent the calendar-year record of precipitation would serve to accurately fix the times and places of drought in the United States. In the beginning of the study the individual records of stations within a State using both the monthly and annual amounts were used. As the work progressed the difficulties of distinguishing the beginning and the ending of drought even from the monthly totals of precipitation led to its abandonment and the substitution of a shorter method based on the averages of precipitation for each year for each of the 42 districts organized into what were formerly known as State weather services, now known as climatological sections, of which as a rule there is one in operation for each State or combination of States, except that the six New England States are organized under the name "New England," and Delaware and the District of Columbia are combined with Maryland. The list of sections with the term of years covered by each section is given in Tables 1 and 2.

In some of the sections the record goes back to the early eighties and in others it does not begin until about 1900, so that the early part of the period is not as fully covered as that part subsequent to 1900. The size of the respective sections varies greatly—say, from about 15,000 square miles in the smallest to 265,896 in the largest. The network of climatological stations is somewhat closer east of the Mississippi than to the westward, especially in Rocky Mountain and Plateau States.

The plan followed was to take out for each State the least annual precipitation that had been recorded during the forty-odd years during the life of the record, then the next lowest annual amount, and so on, on an ascending scale until the tenth year on that scale had been reached. Thus it has been practicable to construct for each State a diagram beginning at the low point and increasing to, say, about 90 per cent of the annual average precipitation. In like manner the year of greatest annual precipitation has been taken out and the nine subsequent years when the next greatest annual amount was received, and so on until the tenth year, on a decreasing scale, had been reached.

Tables 1 and 2 include the tabulation above described, the annual amounts of precipitation being expressed as a percentage of the mean annual or, in other words, the normal for the State.

In Table 1 the scale is an increasing one and in Table 2 a decreasing one.

[1] The substance of this article was presented before the May, 1931, meeting of the American Meteorological Society in Washington, D. C.

TABLE 1.—*Years of deficient precipitation in the United States—Percentage of actual precipitation expressed in percentages of the normal*

States	State means (inches)	Period covered	1		2		3		4		5		6		7		8		9		10	
			Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent	Year	Per-cent
Alabama	52.4	1884–1930	1904	75	1889	83	1914	86	1921	87	1896	87	1910	87	1930	88	1924	91	1897	91	1894	91
Arizona	13.8	1897–1930	1900	60	1889	61	1924	64	1910	66	1928	72	1904	72	1903	72	1902	76	1901	77	1929	82
Arkansas	47.7	1891–1930	1901	75	1924	78	1896	80	1917	85	1899	88	1925	89	1916	89	1914	90	1904	91	1909	92
California	25.1	1897–1930	1898	42	1923	57	1929	61	1917	66	1910	67	1924	69	1930	72	1928	75	1908	75	1897	77
Colorado	16.8	1888–1930	1888	72	1890	72	1893	78	1889	83	1924	84	1903	84	1902	84	1901	86	1900	87	1894	87
Florida	52.5	1892–1930	1927	78	1917	79	1921	87	1895	88	1916	88	1911	90	1913	92	1892	92	1904	92	1898	93
Georgia	49.6	1892–1930	1904	75	1893	82	1927	83	1921	83	1910	88	1916	88	1899	89	1896	91	1914	92	1930	93
Idaho	17.1	1898–1930	1924	74	1929	78	1928	81	1898	83	1904	87	1901	91	1922	91	1905	92	1900	95	1914	95
Illinois	36.4	1878–1930	1901	71	1930	77	1894	80	1914	82	1895	88	1910	88	1879	90	1917	90	1920	91	1925	90
Indiana	39.3	1887–1930	1930	76	1901	79	1895	79	1914	80	1894	82	1908	88	1925	89	1899	90	1889	92	1887	93
Iowa	31.8	1873–1930	1910	63	1894	69	1901	78	1886	78	1889	79	1930	84	1887	84	1895	85	1897	85	1917	88
Kansas	26.8	1887–1930	1917	74	1910	74	1893	75	1894	77	1890	80	1901	80	1913	86	1914	85	1916	90	1921	90
Kentucky	45.1	1889–1930	1930	63	1894	77	1904	79	1901	79	1889	81	1895	85	1918	91	1925	91	1903	91	1914	93
Louisiana	55.3	1891–1930	1924	70	1917	72	1899	77	1904	80	1902	84	1896	85	1921	87	1906	88	1910	89	1903	91
Maryland and Delaware	41.5	1895–1930	1930	56	1895	83	1925	85	1914	87	1904	88	1900	88	1896	89	1910	91	1909	91	1921	92
Michigan	30.5	1888–1930	1930	75	1925	84	1910	84	1889	89	1917	90	1895	93	1894	93	1901	93	1890	94	1923	95
Minnesota	25.7	1886–1930	1910	57	1889	74	1923	78	1929	81	1917	85	1894	84	1912	88	1930	88	1921	90	1887	93
Mississippi	53.2	1888–1930	1889	72	1924	75	1904	79	1896	82	1899	85	1914	88	1930	89	1910	89	1894	90	1895	91
Missouri	40.5	1888–1930	1901	62	1930	77	1894	82	1914	86	1890	88	1910	92	1899	93	1906	93	1918	93	1913	94
Montana	15.4	1895–1930	1904	73	1919	73	1930	80	1895	86	1928	86	1929	86	1900	88	1924	89	1926	91	1918	91
Nebraska	23.5	1876–1930	1894	58	1893	72	1890	74	1910	74	1895	80	1916	81	1899	83	1922	87	1907	87	1898	89
Nevada	8.2	1890–1930	1928	60	1924	69	1910	69	1929	71	1926	80	1898	81	1917	82	1903	87	1919	87	1902	88
New England	41.9	1888–1930	1930	83	1914	84	1910	85	1924	85	1908	85	1894	87	1905	89	1921	89	1911	94	1892	94
New Jersey	46.2	1885–1930	1930	78	1895	81	1918	81	1885	83	1916	83	1921	83	1914	86	1910	86	1923	88	1917	89
New Mexico	14.9	1892–1930	1910	64	1917	64	1892	64	1902	68	1894	72	1924	72	1922	74	1899	74	1903	74	1893	84
New York	39.4	1890–1930	1930	82	1908	85	1895	86	1899	88	1921	91	1923	91	1909	92	1911	93	1914	93	1910	95
North Carolina	50.1	1887–1930	1925	75	1930	77	1911	86	1921	86	1904	87	1926	87	1902	90	1923	90	1897	93	1890	94
North Dakota	17.9	1892–1930	1917	61	1910	69	1929	80	1907	82	1930	83	1913	83	1898	85	1920	87	1894	88	1893	89
Ohio	38.2	1883–1930	1930	71	1895	75	1894	79	1901	86	1900	87	1889	87	1887	88	1925	90	1899	91	1928	92
Oklahoma	32.5	1893–1930	1910	60	1917	69	1901	71	1896	73	1893	80	1894	80	1914	80	1909	84	1924	87	1925	88
Oregon	30.6	1890–1930	1910	60	1917	69	1930	71	1901	71	1896	73	1893	79	1894	80	1914	80	1909	84	1922	87
Pennsylvania	42.4	1888–1930	1930	68	1895	80	1922	83	1900	88	1909	88	1925	89	1910	92	1923	92	1908	93	1904	95
South Carolina	48.3	1887–1930	1925	74	1911	82	1930	84	1904	86	1927	87	1914	91	1887	91	1917	91	1916	92	1909	92
South Dakota	20.8	1890–1930	1894	75	1910	75	1925	77	1895	77	1890	79	1898	79	1917	81	1926	86	1893	87	1930	88
Tennessee	50.1	1884–1930	1930	80	1925	82	1904	82	1894	86	1895	87	1914	89	1885	90	1887	91	1889	92	1908	92
Texas	31.1	1891–1930	1917	53	1893	66	1910	70	1901	72	1909	75	1924	76	1916	80	1925	83	1912	84	1897	89
Utah	13.5	1892–1930	1900	63	1902	69	1892	72	1901	75	1903	77	1898	80	1924	80	1895	80	1928	80	1910	83
Virginia	42.4	1892–1930	1930	59	1925	77	1921	83	1894	85	1904	85	1914	88	1895	91	1912	92	1900	92	1916	93
Washington	36.1	1890–1930	1929	66	1922	68	1911	73	1930	76	1924	78	1925	79	1923	82	1918	84	1913	84	1904	87
West Virginia	43.2	1891–1930	1930	59	1895	76	1904	78	1894	81	1892	89	1900	88	1892	89	1910	89	1914	92	1893	92
Wisconsin	30.6	1891–1930	1910	70	1902	76	1895	77	1930	82	1891	86	1901	86	1923	87	1894	88	1917	89	1925	90
Wyoming	14.6	1899–1930	1902	68	1919	72	1900	77	1910	83	1901	83	1921	87	1914	87	1924	87	1916	88	1903	88
Means				68		75		78		82		83		85		86		88		89		93
NEW ENGLAND STATIONS																						
New Bedford, Mass	46.2	1814–1930	1930	61	1923	68	1919	71	1921	71	1918	71	1846	75	1849	80	1885	81	1856	81	1910	82
Boston, Mass	43.7	1818–1930	1822	63	1846	69	1908	70	1905	73	1837	77	1887	77	1923	78	1930	82	1825	82	1819	82
Lowell, Mass	41.5	1826–1930	1914	67	1846	67	1910	69	1837	74	1908	75	1930	75	1834	76	1835	79	1894	81	1891	82
Amherst, Mass	44.2	1836–1930	1908	70	1924	71	1894	74	1930	74	1864	79	1846	79	1880	81	1843	86	1850	88	1912	88
Providence, R. I	44.2	1832–1930	1914	76	1846	70	1835	70	1930	70	1837	72	1909	77	1915	77	1910	77	1916	79	1849	79

TABLE 2.—*Years of greater than normal precipitation in the United States arranged by States and expressed in percentage of normal*

States	1		2		3		4		5		6		7		8		9		10	
	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent
Alabama	1929	147	1900	126	1919	124	1920	124	1926	117	1923	117	1922	112	1909	111	1888	110	1892	109
Arizona	1905	193	1919	142	1916	124	1923	124	1914	124	1926	121	1906	116	1908	114	1927	114	1915	114
Arkansas	1927	138	1905	133	1923	125	1892	121	1906	120	1898	120	1919	115	1920	115	1913	113	1915	112
California	1923	127	1909	125	1927	121	1891	120	1906	118	1897	117	1915	117	1921	117	1911	115	1914	115
Colorado	1909	169	1906	155	1916	140	1915	136	1907	130	1914	124	1904	122	1911	118	1922	116	1926	108
Florida	1912	124	1924	117	1905	117	1900	116	1928	116	1926	115	1929	112	1920	111	1922	110	1919	110
Georgia	1929	141	1912	128	1928	121	1920	120	1901	116	1900	116	1922	113	1919	112	1906	112	1924	110
Idaho	1927	134	1909	130	1912	127	1906	122	1916	122	1907	120	1917	119	1913	117	1915	113	1925	112
Illinois	1927	136	1882	132	1883	130	1898	120	1881	121	1884	119	1909	119	1926	119	1902	116	1915	116
Indiana	1890	126	1927	125	1909	123	1929	120	1898	117	1907	114	1913	112	1926	111	1905	110	1923	109
Iowa	1881	139	1902	139	1909	127	1915	124	1896	117	1919	117	1876	116	1892	116	1928	113	1884	112
Kansas	1915	152	1902	128	1928	125	1927	121	1908	121	1923	121	1898	120	1903	118	1909	117	1891	116
Kentucky	1890	130	1923	120	1927	118	1898	116	1919	116	1915	116	1909	114	1910	112	1926	112	1891	110
Louisiana	1905	139	1923	129	1919	125	1922	121	1926	119	1900	119	1912	117	1913	117	1929	116	1920	114
Maryland and Delaware	1902	119	1907	119	1906	116	1919	115	1903	114	1924	112	1901	109	1928	109	1926	107	1905	106
Michigan	1893	114	1911	114	1890	113	1916	112	1892	110	1905	109	1928	109	1926	108	1903	107	1902	107
Minnesota	1905	130	1903	129	1906	123	1896	122	1890	118	1900	116	1904	116	1908	116	1902	116	1909	115
Mississippi	1923	134	1919	131	1900	125	1912	125	1905	123	1920	119	1929	113	1911	113	1922	112	1909	110
Missouri	1927	134	1898	133	1915	122	1929	116	1928	113	1905	113	1909	112	1902	112	1896	111	1921	108
Montana	1927	134	1908	132	1909	128	1915	123	1916	123	1911	121	1906	121	1923	119	1896	115	1912	113
Nebraska	1915	152	1905	135	1881	132	1883	132	1891	131	1902	124	1923	120	1903	117	1906	115	1908	115
Nevada	1906	194	1891	174	1901	161	1907	160	1890	159	1909	136	1913	136	1894	135	1896	131	1904	131
New England	1888	134	1898	122	1890	121	1889	118	1920	116	1901	115	1902	112	1897	112	1900	110	1927	110
New Jersey	1889	138	1902	128	1903	121	1898	113	1888	113	1919	113	1920	112	1907	112	1901	112	1897	112
New Mexico	1919	141	1905	141	1923	131	1914	131	1911	121	1915	119	1926	117	1897	111	1921	111	1929	111
New York	1890	126	1927	115	1892	111	1898	111	1903	110	1901	110	1902	109	1929	109	1893	108	1925	106
North Carolina	1901	125	1929	124	1906	119	1908	115	1922	114	1920	113	1928	112	1888	110	1891	109	1924	109
North Dakota	1896	132	1927	121	1916	116	1912	113	1905	112	1908	112	1906	111	1921	111	1901	109	1915	109
Ohio	1890	132	1929	120	1883	119	1913	118	1898	115	1926	115	1921	113	1927	113	1907	113	1909	113
Oklahoma	1908	156	1915	140	1923	138	1902	125	1905	123	1927	122	1926	120	1905	112	1928	112	1920	112
Oregon	1896	183	1894	166	1893	160	1899	157	1902	151	1904	149	1891	147	1897	143	1895	143	1907	137
Pennsylvania	1889	124	1890	121	1902	112	1927	112	1919	111	1903	110	1888	109	1891	108	1898	108	1901	108
South Carolina	1929	138	1928	128	1922	121	1924	119	1901	115	1906	114	1888	114	1912	114	1893	111	1908	111
South Dakota	1915	142	1906	140	1920	137	1905	133	1908	125	1892	121	1896	119	1909	118	1927	115	1900	114
Tennessee	1929	119	1890	115	1923	115	1919	115	1920	113	1884	111	1912	109	1922	109	1926	109	1892	108
Texas	1919	147	1900	137	1905	135	1923	129	1914	122	1926	118	1913	117	1920	110	1907	110	1902	110
Utah	1909	149	1906	140	1920	127	1927	127	1921	126	1907	123	1916	123	1908	113	1922	113	1897	113
Virginia	1902	121	1901	118	1906	117	1924	113	1893	110	1920	109	1929	109	1908	106	1903	106	1922	106
Washington	1896	128	1894	120	1891	120	1899	117	1902	117	1927	117	1893	115	1897	110	1900	104	1909	99
West Virginia	1907	122	1926	116	1913	113	1927	113	1924	110	1898	110	1919	110	1911	110	1929	107	1891	107
Wisconsin	1911	121	1903	117	1905	117	1906	117	1926	116	1892	115	1900	114	1916	111	1919	109	1928	108
Wyoming	1915	133	1923	133	1912	127	1927	125	1906	122	1908	120	1909	113	1905	111	1918	111	1913	111
Means		139		130		125		122		119		117		116		116		113		112
New Bedford, Mass, 1814–1929	1829	142	1830	141	1827	136	1850	136	1898	136	1890	134	1831	133	1823	130	1868	123	1888	120

The chief interest in the two tables is historic; the data in them will serve as a reference point for future studies of excess or deficit in annual precipitation.

Obviously the percentage of the normal that is received in the dry regions of the Southwest is less than for the humid sections east of the Mississippi; somewhat unexpected results are the relatively low percentage of rain that is received in dry years in California, Oregon, and Washington, the range being from 42 per cent in California to 66 per cent in Washington. In Arizona and parts of New Mexico low percentages were to be expected. Arizona, especially the lowlands of the western portion, occasionally receives in very dry years at individual stations less than 1 per cent of the average annual precipitation. At the higher levels individual stations receive nearly as great a percentage of the annual as do points situated in the humid regions of the East. The percentage of the annual precipitation received by the Rocky Mountain States of Colorado, Idaho, and Montana is greater than was expected. Florida in the South, Indiana and Michigan in the North, and New York and New England in the Northeast show the greatest stability, or in other words less percentage variation than in other places in the humid region. The New England record as given in Table 1 depends on the observations for the period 1888–1930; if, however, the individual stations having from 50 to 100 years of observations be considered smaller percentages will be found to obtain; thus for the driest, second, and third driest the percentages were 66, 69, and 71, respectively. (See records of five individual long-record stations at bottom of Table 1.)

The data of Table 1 establishes the fact that the year 1930 set the record for extreme dryness in the United States as a whole; the States of Maryland and Delaware, the two Virginias, Kentucky, and Ohio standing in the order named with respect to the percentage of the normal precipitation that was received. The drought of 1901 in Missouri, those of 1910 in Iowa, 1917 in North Dakota, Texas, and possibly other parts of the country, were more intense, precipitation being considered, than in 1930.

Following is a comparison of the average percentage of the normal precipitation in all recorded droughts as shown at the bottom of Table 1 with that of England and Wales in the five driest years in Great Britain.[1]

	Per cent
United States, average of all droughts	68
England and Wales, drought of—	
1921	71
1887	74
1854	77
1864	78
1870	82

It is of additional interest to observe that while drought in the United States is not always synchronous with drought in the British Isles it is more so than would be required by chance. The year of greatest drought in Britain—1921—was also a warm and droughty year in the United States, the second greatest drought in Britain—1887—was droughty in some sections but was not so severe and general as in 1886, the year previous; 1854–55 and 1856–57 were all more or less droughty years in this country, but the droughts were local in character rather than general and this is also the case in the early seventies.

As has been found in earlier studies of the precipitation in the United States [2] the fact that the smaller the average rainfall the greater is the variation from year to year is again confirmed; for this and other reasons the actual precipitation in Tables 1 and 2 is given as a percentage of the normal for the section. There are several more or less distinct groups of rainfall distribution in the United States; following is a rather coarse grouping:

1. The Pacific coast and Plateau States, embracing Washington, Oregon, California, Nevada, Utah, Arizona, and New Mexico. This group is characterized by the greatest annual variation in precipitation to be found in continental United States.

2. The Plains States of North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, Missouri, Iowa, and Minnesota. The three last named while not strictly Great Plains States may be included in that group because of similar rainfall distribution. They form the largest group and are characterized by what may be called the continental type of rainfall distribution.

3. The Gulf States of Louisiana, Mississippi, Alabama, and Florida. This group receives a greater precipitation than either of the two first mentioned and the annual rainfall may be said to be much more dependable; that is, it varies less from the normal.

4. Finally the group of Northeastern States have the most dependable precipitation of any part of the United States. I include in this group New England, New York, New Jersey, Pennsylvania, and Michigan.

In Table 3 will be found a summary showing the percentage of the annual precipitation for the driest year, the second and third driest on the average of each group. Likewise the average percentage of the greatest, the second, and third greatest is also shown.

TABLE 3.—*Percentage of the average precipitation in the three years of deficient and the three years of greatest precipitation in the groups of States numbered 1 to 4 on the left of the table*

Groups	Least			Greatest			Range
	1	2	3	1	2	3	
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
No. 1	59	65	67	167	149	136	108
No. 2	54	72	77	143	133	129	79
No. 3	74	77	82	136	126	123	62
No. 4	78	83	84	127	120	116	49

The sequence of dry years, Figure 1.—The data of Table No. 1 have been summarized and reproduced as Figure 1, in order to show graphically the sequence and grouping of the dry years; column 1 of that figure shows, as previously explained the number of sections, if any, in which the least annual precipitation of the whole series of years was recorded; column 2 the number in which the next to the least was recorded; and so on, so that the series of steps to the right of column 1 may be considered as a series of annual precipitation amounts which approach but do not reach the normal.

The full lines in the figure show those years that may be considered as falling within the group of major dry years. These are 1889, 1894, 1901, 1910, 1917, 1921, 1924, and 1930. There is a slight tendency in the groups to spread fan shaped toward the right, thus indicating that the peak dry year is preceded in most cases by gradually diminishing precipitation during one or two years prior to that year, thus the peak dry year of 1894 was preceded by diminishing precipitation in 1892 and 1893 and was followed by somewhat dry years in 1896–97. This is merely another way of saying that severe droughts gradually approach a peak year and that the return of normal conditions is brought about gradually.

[1] Quart. Jour. Roy. Met. Soc. 48: 140.
[2] Henry, Alfred J. Rainfall of the United States, Weather Bureau Bulletin D, Washington, 1897.

DRY YEARS – SCALE 1 TO 10

	1	2	3	4	5	6	7	8	9	10	Total
1879							1				1
85				1			1				2
86				1							1
87							3	1		2	6
88	1										1
89	1	3		2	2	1			2		11
90		1	1		3					1	6
91					1						1
92			2		1		1	1		1	6
93		3	2		1	1			1	3	11
94	2	2	3	4	2	3	2	1	2	2	23
95		5	3	3	3	2	1	2		1	20
96			1	2	2	1	1	1			8
97									3	2	5
98	1			1		3	1			2	8
99			1	1	2		3	2	2		11
1900	2		1	1	1	2	1		3		11
1	3	1	2	5	1	3		2	1		18
2	1	2		1	1		2	1		1	9
3				1	1	1	1	1	2	2	8
4	3		4	2	4	1			2	2	18
5							1	1			2
6								2			2
7				1					1		2
8		1			1	1			2	1	6
9					2		1	1	2	2	8
10	6	3	4	3	2	3	1	4	1	2	29
11		1	2			1		1	1		6
12							1	1	1		3
13						1	2		1	1	5
14		1	1	4		4	3	3	3	2	21
16					2	2	2		3	1	10
17	3	5		2	2		2	2	1	2	19
18			1				1	1	1	1	5
19		2							1		3
20								1	1		2
21			2	3	1	2	1	1	1	2	13
22		1	1				2	1		1	6
23		1	1			1	2	2	1	1	9
24	2	3	1	1	2	3	1	3	1		17
25	2	3	2			3	1	3		3	17
26					1	1		1	1		4
27	1		1		1						3
28	1		1		2			1	1	1	7
29	1	1	2	2		1				1	8
30	12	3	3	2	1	1	3	1		2	28
Sums	42	42	42	42	42	42	42	42	42	42	420

FIGURE 1.—Chronological list of years with deficient precipitation on a scale of 1 to 10. (See text)

WET YEARS – SCALE 1 TO 10

	1	2	3	4	5	6	7	8	9	10	Total
1876							1				1
81	1		1		1						3
82		1									1
83			2	1							3
84						2				1	3
88	1				1		2	1	1		6
89	2			1							3
90	4	2	2		1						9
91		1	1	1	1		1	1	1	3	10
92			1	1	1	2		1	1	2	9
93	1		1		1		1				4
94		2	–					1	1		4
96	3			1	1		1				6
97						1		4	4	2	11
98		2		4	2	2	1				11
99				2	1						3
1900		2	1	1		3	1			1	9
1	1	1	1		2	2	1			1	9
2	2	3	1	1	2	1	2	1	1	2	16
3		2	1		2	1		2	2		10
4						1	2			1	4
5	3	3	3	1	3	2		2	2	1	20
6	1	3	4	2	3	1	3				17
7	1	1		1	1	3		1	1	1	10
8	1	1		1	2	2		4	4	2	17
9	2	2	3			1	4	2	2	4	20
10								1	1		2
11	1	1			1	1		3	3		10
12	1	1	2	2			2	1	1	1	11
13			1	1			3	2	2	1	10
14				1	2	1				1	5
15	4	1	1	3		2	1			4	16
16			3	1	2		1	1	1		9
17							1				1
19	2	2	2	2	2	2	2	1	1	1	17
20			2	2	2	3	1	3	3	2	18
21					1		1	2	2	1	7
22			1	1	1		2	1	1	1	8
23	2	3	4	2		2	1	1	1	1	17
24		1		2	1	1				2	7
25										2	2
26		1			3	4	2	3	3	1	17
27	5	3	2	5		2		1	1	1	20
28		1	2		2		2	1	1	1	10
29	4	2		2			3	1	1	1	14
30											0
Sums	42	42	42	42	42	42	42	42	42	42	420

FIGURE 2.—Chronological list of years with greater than the normal precipitation. (See text)

The dry year 1910 is seemingly in a class by itself, as is also 1917. The onset of the first named was quite sudden as compared with the others shown in the figure. The year 1917 was one of maximum spottedness of the sun and that fact has been used by some in an effort to tie up the occurrence of droughts with the occurrence of many sun spots; the difficulty that must be faced by them is that the record shows that droughts occur almost simultaneously with both increasing and diminishing sun-spot numbers. (See Table 4.)

TABLE 4.—*Droughts in the United States and sun spots*

Year	Sun-spot curve		Smoothed sun-spot numbers			Nearest epoch of—	
	Rising	Falling	January	December	Year	Minimum	Maximum
1854		F	28.2	15.6	21.0	1856.0	
1856	R		3.3	9.3	5.2	1856.0	
1857	R		10.5	36.0	23.0	1856.0	
1860		F	97.2	90.6	94.8		1860.1
1863		F	51.9	43.2	45.4		1860.1
1864	R [1]	F	44.8	41.3	45.2	1867.2	
1870	R		110.0	135.4	131.8		1870.6
1881	R		47.0	62.4	54.4	1878.9	
1893	R		78.0	86.7	83.7		1894.1
1894		F	87.9	71.3	79.1		1894.1
1895		F	67.7	52.5	61.5		1894.1
1901		F	4.8	2.8	3.4	1901.7	
1910		F [2]	31.5	12.8	21.0	1913.6	
1916	R		57.8	68.7	59.1		1917.6
1917	R		73.4	98.3	96.2		1917.6
1924	R		0.5	16.5	16.7	1923.6	
1930		F	63.7	28.0			1928.0

[1] Rising followed by falling.
[2] The driest year in the United States in forty-odd years.

The 1924–25 drought had its beginning in 1921 and was distinguishable as late as 1926, although in that year a number of States had more than the average precipitation. It happens, not infrequently, that one and the same year may yield abundant rain in one part of the country and withhold it in another, as illustrated by 1927, the year of the great Mississippi flood. In that year Florida, Georgia, and South Carolina suffered more or less from drought.

YEARS OF GREATEST PRECIPITATION

The chronological record of years with greater than the normal precipitation as summarized from the data of Table 2 is presented in Figure 2. In that figure I have indicated the probable grouping of years of greater than the normal precipitation by inclosing them in continuous lines. These years occur also in groups as in the case of years of deficient rainfall. The groups are centered about 1890, 1898, 1902, 1905, 1909, 1912, 1915, 1919, 1923, and finally in 1927, 1928, and 1929.

The average interval between these dates is roughly four years.

If the figures of the extreme right-hand column of Tables 3 and 4 be smoothed by the formula $\left(\frac{a+2b+c}{4}\right)$ and the smoothed values be plotted against time as abscissa the resulting curve indicates a period of approximately four years between epochs of maximum and minimum. I attach no great importance to these curves, since the smoothing process distorts or rather displaces the epochs of maximum and minimum and reduces the amplitude of the oscillations.

Figure 2 is complementary to Figure 1, since it presents the grouping of the opposite extreme in the annual precipitation. Viewing the two figures one must be struck with the apparent absence of chance in the annual distribution of precipitation; rather these two figures favor the idea that the years of little and much rainfall succeed each other in a wave like sort of motion which advance from west to east and perhaps in due course encircle the globe. It is also possible to identify in them the well-known Brückner years of dry and wet weather said to repeat themselves in a period of 35 years.

Another outstanding feature to which attention is invited is that years of drought do not come suddenly and unheralded but almost uniformly preceded by one or two years of diminished precipitation in various parts of the United States; likewise peak dry years are sometimes followed immediately by one or two years of fairly good rains apparently intercalated in a series of dry years as in 1902–03 and again in 1915–16.

Conclusions.—The facts hereinbefore presented lead to the belief that in the great majority of cases the total annual precipitation may be used as a criterion on drought; it must, however, be used intelligently, bearing in mind that the area under consideration with up to 70 per cent of its annual normal rainfall may have been very dry in spots but as whole the deficit may not have been equally pronounced.

In the Pacific coast and Plateau States any one year with but 60 per cent of its annual precipitation may be classed as a dry year. In the Great Plains States, excepting South Dakota, 65 per cent, while not as low as has been reached in past droughts may be accepted as a measure of severe drought. In the Gulf States the range is from 70 to 75 per cent and in the Northeastern States the lower limit is from 75 to 85 per cent.

SOLAR RADIATION INTENSITIES WITHIN THE ARCTIC CIRCLE

By HERBERT H. KIMBALL

[Weather Bureau, Washington, D. C., April 15, 1931]

In summaries of solar radiation measurements prepared by the author,[1] the following stations within, or practically on the Arctic Circle have been listed:

Abisko, Sweden, latitude 68° 21′ N., longitude 18° 49′ E., altitude 390 meters.

Jokkmokk, Sweden, latitude 66° 36′ N., longitude 19° 51′ E., altitude 255 meters.

Mount Evans, Greenland, latitude 66° 51′ N., longitude 50° 50′ W., altitude 394 meters.

Rovaniemi, Finland, latitude 66° 29′ N., longitude 25° 44′ E., altitude 200 meters.

Treurenberg, Spitzbergen, latitude 79° 55′ N., longitude 16° 52′ E., altitude 9 meters.

At these stations solar radiation intensity at normal incidence was measured. Now we may add to the above list Green Harbor, Spitzbergen, latitude 78° 00′ N., longitude 14° 05′ E., with continuous measurements of the total solar radiation (direct+diffuse) received on a horizontal surface.

SOLAR RADIATION MEASUREMENTS AT GREEN HARBOR, SPITZBERGEN

At the second general assembly of the International Geodetic and Geophysical Union at Madrid, in 1924, the

[1] Measurements of solar radiation itensity and determinations of its depletion by the atmosphere. MONTHLY WEATHER REVIEW, 55: 155, April, 1927; 58: 43, February, 1930.

Meteorological Section set aside the sum of £400 for the purchase of self-recording pyrheliometers or pyrgeometers for use in northern Canada or Spitzbergen, New Zealand or Samoa, Brazil or Belgian Congo, and the South Orkneys.

For Spitzbergen a Gorczyński recording solarimeter was obtained, and was installed by Dr. H. U. Sverdrup at Green Harbor at the beginning of September, 1927. The instrument is designed to give a continuous record of the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky. In transmitting a summary of the measurements Doctor Sverdrup makes the following statement:

> These records have been obtained by means of a Gorczyński recording instrument which was delivered by Kipp & Zonen, and installed by myself at the Norwegian radio station. The records have been reduced at the Geophysical Institute in Bergen, using the constant for the instrument which was obtained from the makers. This constant, according to comparisons with records from Finland, can be regarded as fairly accurate. No absolute observations were undertaken at Green Harbor, since there was no trained observer at the station.

As tabulated at Bergen the average intensity of solar radiation is given for each hour of each day, central on the full hour. The maximum intensity for each day is also given. From the latitude of Green Harbor, and neglecting atmospheric refraction, we would expect the sun to appear above the southern horizon on February 17 and to disappear below it on October 25. Actually, the first sunshine in spring was recorded on February 26 and the last in fall on October 18. Also, we would expect solar radiation throughout the 24 hours from April 21 to August 21. Actually, the first day in spring with solar radiation during every hour is April 29, although recorded at midnight after the 25th. The sun was continuously above the horizon on August 9 when the record ended.

TABLE 1.—*Total solar radiation (direct+difuse) measured at Green Harbor, Svalbard. Latitude 78° 00′ N., longitude 14° 05′ E.*

[Gram-calories per square centimeter of horizontal surface]

Week beginning	Average daily	Maximum daily	Maximum hourly	Maximum per minute
1927	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 4 [1]	131	184	26	0.55
Sept. 10	107	135	20	0.38
Sept. 17	56	72	13	0.33
Sept. 24	45	68	14	0.19
Oct. 1	15	17	4	0.14
Oct. 8	12	19	5	0.12
Oct. 15 [2]	5	7	3	0.05
1928				
Feb. 26	7	11	3	0.06
Mar. 4	18	27	5	0.12
Mar. 11	43	50	8	0.21
Mar. 18	75	86	13	0.24
Mar. 25	101	131	19	0.38
Apr. 1	133	185	23	0.41
Apr. 8	180	216	26	0.58
Apr. 15	233	301	31	0.69
Apr. 22	320	373	35	0.83
Apr. 29	303	355	37	0.83
May 6	428	447	43	0.92
May 13	450	502	44	0.91
May 20	445	517	50	1.10
May 27	505	521	46	1.09
June 3	447	592	47	0.91
June 10	562	[3] 652	53	1.43
June 17	615	644	49	0.85
June 24 [3]	562	643	49	0.81
July 2	480	622	51	1.03
July 9	296	506	46	1.07
July 16	358	536	44	0.90
July 23	340	443	40	0.73
July 30	340	416	38	0.76
Aug. 6 [4]	273	365	33	0.66

[1] 6 days only. [2] 4 days only. [3] 8 days. [4] 4 days only.
[3] The sum of maximum hourly amounts for the respective hours=712 gr. cals.

In Table 1 the data as originally tabulated have been summarized by weeks, giving for each week the average daily amount of radiation expressed in gram-calories per square centimeter of horizontal surface, and also the maximum per day, per hour, and per minute. There are frequent gaps in the record, especially at about 8 a. m. The average daily amounts are based on such data as has been furnished, with interpolations where practicable.

In June the maximum total is less than that computed by me for June 21 with cloudless sky at Latitude 60° and 90° north, and the average daily total is greater.[2] From this I conclude that at Green Harbor in June one does not often find 24 hours with skies continuously free from clouds and fog, and that, on the other hand, the average cloudiness is not as great as has been observed at other Arctic stations, or at least that this was the case in 1928.

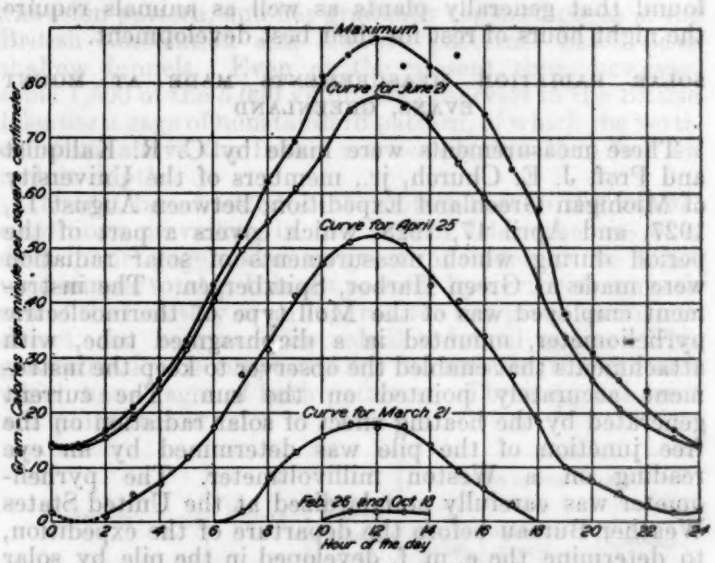


FIG. 1.—Diurnal march of solar radiation at Green Harbor, Spitzbergen, for different epochs of the year. (The time scale is on apparent, or true solar time.)

Without having seen the original record sheets, there appears to be some question about the accuracy of the maximum radiation per minute (1.43 gram-calories) recorded on June 10. At noon on this day the solar altitude was only slightly in excess of 35°. The intensity of direct solar radiation could hardly have exceeded 1.5 gram-calories per minute per square centimeter, and its vertical component would be $1.50 \times 0.574 = 0.86$, leaving 0.57 gram-calories per minute per square centimeter for sky radiation. This amount could have been received only under the most favorable conditions for reflection of light from clouds between the sun and the zenith. A well-authenticated increase in the intensity of solar radiation of 20 per cent due to reflection from clouds occurred at Mount Weather, Va., on July 28, 1912.[3] The percentage increase at Green Harbor appears to have been considerably greater, or from 25 to 30 per cent. Possibly reflection from the snow and ice covered ground surface to the under side of the cloud and then back to the earth would account for the excessively high radiation intensity in question.

In Figure 1 the diurnal march of radiation is represented by the hourly intensities for the first day in spring and the last day in autumn on which records were ob-

[2] Kimball, Herbert H. Amount of solar radiation that reaches the surface of the earth on the land and on the sea, and methods by which it is measured. MONTHLY WEATHER REVIEW, vol. 56:393, 1928.

[3] Kimball, Herbert H., and Miller, Eric. The Influence of Clouds on the Distribution of Solar Radiation. Bull. Mt. Weather Obs., 5:166, 1912.

tained, by the hourly averages for March 18–24, the week of the vernal equinox, for April 22–28, the first week on which radiation was recorded at midnight, for June 17–23, the week of the summer solstice, and finally a curve representing the maximum average hourly intensities recorded in each of the 24 hours. The sum of these last-named hourly averages multiplied by 60 gives the maximum daily radiation with clear skies for the year.

It is to be noted that the average daily amount for the three weeks centering on the summer solstice is greater than the average of the daily normals for this period for any stations in the United States except Twin Falls, Idaho, and Fresno, Calif., as given in Table 4, MONTHLY WEATHER REVIEW for February, 1930, volume 58, page 45.

What must be the effect upon plant and animal life of this stimulus of continuous solar radiant energy during four months of the year? In lower latitudes it has been found that generally plants as well as animals require the night hours of rest for their best development.

SOLAR RADIATION MEASUREMENTS MADE AT MOUNT EVANS, GREENLAND

These measurements were made by C. R. Kallquist and Prof. J. E. Church, jr., members of the University of Michigan Greenland Expedition, between August 13, 1927, and April 17, 1928, which covers a part of the period during which measurements of solar radiation were made at Green Harbor, Spitzbergen. The instrument employed was of the Moll type of thermoelectric pyrheliometer, mounted in a diaphragmed tube, with attachments that enabled the observer to keep the instrument accurately pointed on the sun. The current generated by the heating effect of solar radiation on the free junction of the pile was determined by an eye reading on a Weston millivoltmeter. The pyrheliometer was carefully standardized at the United States Weather Bureau before the departure of the expedition, to determine the e. m. f. developed in the pile by solar radiation of known intensity. It was hoped to recalibrate the instrument after its return from Greenland. Unfortunately, however, while the pyrheliometer was received back in excellent condition the millivoltmeter was ruined by the upsetting of a boat in which it was being transported. A satisfactory recalibration of the complete apparatus was therefore impossible.

A brief summary of these measurements was given by me in a paper in the Review for February, 1930.[4] They are here summarized in more detail.

TABLE 2.—*Pyrheliometric readings made by Prof. J. E. Church, jr., during trip to and on inland ice. Direction of travel, east from latitude 66° 50′ N., longitude 51° W., total distance, 30 miles*

[Gram-calories per minute per square centimeter of normal surface]

Date	Air mass									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
1927	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Aug. 13, a. m.	1.43	1.32	1.20							
Aug. 13, p. m.		1.33	1.23	1.15	1.07	1.00	0.94	0.88	0.84	0.80
Aug. 14, a. m.	1.44	1.35	1.26							
Aug. 14, p. m.		1.33	1.24	1.16	1.08	1.02	0.96	0.91	0.86	0.81
Aug. 15, a. m.	1.45	1.33	1.23	1.16	1.09	1.03				
Aug. 15, p. m.		1.33	1.23	1.12	1.03	0.95	0.89	0.86	0.84	0.82
Aug. 16, a. m.	1.30	1.22	1.16	1.09	1.02	0.96	0.91			
Aug. 16, p. m.			1.16	1.10						
Aug. 17, a. m.	1.40	1.32	1.25	1.18	1.12	1.07	1.04	1.01	0.98	0.97
Aug. 17, p. m.		1.34	1.21	1.10						
Aug. 20, a. m.	1.38	1.29	1.20	1.14	1.08	1.04	1.00	0.96		
Means	1.40	1.32	1.22	1.13	1.07	1.01	0.96	0.92	0.88	0.85

[4] Kimball, Herbert H. Measurements of solar radiation intensity and determinations of its depletion by the atmosphere. Monthly Weather Review, 58:43.

Table 2 summarizes measurements made by Professor Church, between August 13 and 16, inclusive, on the journey from the shore to the inland ice, at altitude of from 250 to 450 feet above sea level; on August 17 at the edge of the ice where the altitude was about 950 feet and on August 20 on the inland ice, at an altitude of between 1,600 and 1,800 feet. The distance covered was about 30 miles, and the direction traveled was approximately east, so that there was little change in latitude. The change of correction necessary to reduce forty-fifth meridian time to apparent time was taken into account in computing solar altitudes corresponding to the time at which the measurements were made. Solar altitudes at noon varied from 37° 45′ on August 13 to 35° 32′ on August 20, corresponding to air masses 1.63 and 1.72, respectively. The intensities for air mass 1.5 and 1.0 were therefore obtained by extrapolation.

Table 3 summarizes measurements made by C. R. Kallquist at Mount Evans, Greenland, on the inland ice, at an altitude of 1,228 feet (374 meters). Slight extrapolations have in a few cases been necessary to obtain the intensities tabulated. In general, the readings indicate a very pure and dry atmosphere, as is shown by the values for the atmospheric transmission given in Table 4.

TABLE 3.—*Pyrheliometric readings made by C. R. Kallquist at Mount Evans, Greenland. Latitude 66° 51′ N., longitude 50° 50′ W., altitude 1,228 feet*

[Gram-calories per minute per square centimeter of normal surface]

Date	Solar altitude												Vapor pressure
	30.0°	23.5°	19.3°	16.4°	14.3°	11.3°	9.3°	7.8°	6.8°	3.1°	1.8°	0.7°	
	Air mass												
	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	15.0	21.0	30.0	
1927	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 6, p. m.	1.32	1.26	1.20										4.75
Sept. 7, p. m.	1.31	1.26											4.37
Sept. 17, p. m.		1.34	1.25	1.19	1.15	1.08	1.01			0.42			
Sept. 18, p. m.		1.30	1.24	1.19	1.14	1.07	1.02				0.62		
Sept. 20, p. m.		1.40	1.23	1.22						0.65			2.74
Sept. 22, p. m.				1.18	1.14	1.08							
Sept. 24, p. m.		1.31	1.25	1.20									2.62
Sept. 25, p. m.			1.30	1.22	1.18	1.11							2.74
Means	1.32	1.31	1.25	1.20	1.15	1.08	1.02			0.54	0.62		3.44
Oct. 12, a. m.				1.28	1.21	1.10	1.03						2.16
Oct. 12, p. m.				1.22	1.16	1.06							
Means				1.25	1.18	1.08	1.03						
1928													
Feb. 18, p. m.						1.25	1.14	1.10	1.09	0.76		0.27	0.38
Mar. 20, a. m.		1.47	1.39	1.34	1.30								0.51
Mar. 20, p. m.		1.56	1.39		1.32	1.18	1.07						
Means		1.52	1.39	1.34	1.31	1.18	1.07						
Apr. 3, a. m.	1.47	1.38	1.30	1.22									1.52
Apr. 3, p. m.	1.50	1.38	1.29	1.24	1.19								
Apr. 4, a. m.	1.44	1.40	1.33	1.28									0.58
Apr. 4, p. m.		1.35	1.25	1.15	1.06								
Apr. 17, a. m.	1.38												2.74
Apr. 17, p. m.	1.34	1.28	1.22	1.18	1.12	1.03	0.94	0.86					
Means	1.43	1.36	1.28	1.21	1.12	1.03	0.94	0.86					1.61

TABLE 4.—*Atmospheric transmission for solar radiation*

Date	Solar altitude	Air mass		Intensity	Vapor pressure	Precipitable water	Atmospheric transmission		Difference
		m	$m\frac{P}{760}$	I			I/I_2	Computed	
1928	°			*Gr. cal. min. cm.²*	*Millimeters*	*Centimeters*			
Mar. 20	14.3	4.0	3.80	1.31	0.51	0.11	0.675	0.705	0.030
Do	19.3	3.0	2.85	1.39	0.51	0.11	0.716	0.752	0.036
Apr. 17	30.0	2.0	1.90	1.36	2.74	0.605	0.707	0.746	0.039
Sept. 6–7	30.0	2.0	1.90	1.31	4.57	1.00	0.693	0.721	0.028

In this table m is the value of the length of the path of the solar rays in passing through the atmosphere in terms of the length when the sun is in the zenith, as computed by Bemporad. In the following column m is multiplied by the ratio of the atmospheric pressure to standard pressure, or 760 mm. I is the measured intensity of solar radiation, and I_R^2 is the mean value of the solar constant, I_o divided by the square of the earth's radius vector in terms of its mean value. The computed atmospheric transmission is obtained from the MONTHLY WEATHER REVIEW, February, 1930, volume 58, page 52, Figure 1. The atmospheric depletion indicated by this computed transmission includes all that Fowle found correlated with pure dry air and water vapor. The difference between the two transmission values must be attributed to depletion by impurities in the atmosphere.

Comparing these differences with corresponding differences for Washington, D. C.; Madison, Wis.; Lincoln, Nebr.; and Davos, Switzerland, given on page 51 of the REVIEW cited above, it is seen that the atmosphere at Mount Evans, Greenland, is relatively free from dust at all seasons of the year, as we would expect it to be.

RAIN-GAGE FUNNELS OF DIFFERENT DEPTHS

By JOHN GLASSPOOLE, M. Sc., Ph. D.

[Meteorological Office, London]

With reference to the article on "Rainfall catch as affected by different depths of funnels in the rain gage,"[1] it may be of interest to refer to some of the experiments which have resulted in the adoption of the deep-funnel gage as the standard pattern in the British Isles.

At the majority of the official stations of the Meteorological Office the 8-inch gage is used, in continuation of a practice which dates back to about 1870. According to the current specification the funnel has vertical walls 5¾ inches deep. By far the greater number of gages in use in the British Isles are, however, 5 inches in diameter. In the case of the standard "Snowdon" gage the diameter is 5 inches and the depth of the vertical walls is about 4 inches. In the Meteorological Office version of this gage the depth of the vertical walls is 4 1/16 inches and the funnel proper slopes at 33½° to the horizontal. The rain is collected in a bottle holding about 3½ inches, standing in a copper can, the total capacity of which is about 9 inches. The inner can stands in an outer can, on to the top of which the funnel fits. The base of the outer can is splayed so that the gage can be fixed firmly in the ground at such a depth that the rim is exactly 1 foot above the surface. Somewhat similar gages, but of larger capacity are used for monthly measurements. In these gages a dip rod is used, but only for the purpose of giving a rough check reading. The actual measurement is made by pouring the water into a cylindrical glass measure graduated in inches and tenths. For daily observations, measuring glasses with taper bases are used. These glasses are subdivided to 0.01 inch or 0.1 mm., the former have an additional graduation at 0.005 inch for the purpose of making it easy to decide whether a small amount is to be counted as a "trace" or as 0.01 inch. This is important because in the latter case the day ranks as a rain day. These particulars are given in some detail because it is important, in this connection, to remember that the instruments used in the British Isles are very different from those used in America.

According to Mr. R. H. Scott, a former head of the Meteorological Office, the deep-funnel gage was invented by Quetelet. A gage with a vertical wall of 6.3 inches is described in "Sur le Climat de la Belgique, cinquieme partie" by Quetelet, published in 1852. The introduction of the deep-funnel gage in the British Isles was due mainly to Mr. G. J. Symons, the founder of the British Rainfall Organization, now incorporated in the Meteorological Office. It was first used about 1864, and subsequently on Mount Snowdon. It became known as the Snowdon pattern, and has gradually replaced gages of the British Association and Howard patterns, which have shallow funnels. Even at the present time, however, some 1,500 of the 5,000 voluntary observers in the British Isles use a gage of nonstandard pattern, of which the vertical walls above the funnel are usually less than half an inch in depth.

It must be admitted at the outset that in the normal conditions prevailing in the British Isles, the use of a deep-funnel gage makes no great difference to the measured annual total. It is not possible by a critical comparison of the monthly or annual records in a given locality to detect the returns from shallow-funnel gages. This generalization is supported by the records from stations which have gages of both patterns. Three typical cases are quoted below:

Station	County	Period of observation	Mean annual values			
			Shallow funnel	Snowdon funnel	Difference	
			Inches	*Inches*	*Inches*	*Per cent*
Tenterden	Kent	1876–1921	28.28	27.76	+0.52	+1.9
Swinton House	Berwick	1914–1921	26.16	26.03	+.13	+.5
Purley	Surrey	1907–1920	31.16	31.48	−.28	−.9

The differences year by year depart little from these mean values. It should be noted, however, that if any obvious error occurred—e. g., during snow—the same amounts were generally adopted for both gages. Some observers have noted that the shallow gage gave a slightly larger number of rain days.

It has been possible, however, to attribute inconsistencies in the *daily* readings at adjacent stations to the use of a shallow-funnel gage at one or more of them. During periods of snow and of intense rain or hail, the standard gage invariably retains a better sample of the precipitation. Although there is obviously more risk of loss with the shallow-funnel gage by outsplashing from the funnel during intense rain or hail few comparative readings are on record. Even when such readings are available some doubt often exists as to whether they are strictly comparable owing to such precipitation being particularly local.

Some of the earliest experiments in the British Isles on this subject were made by Colonel Ward, at Calne (Wiltshire) during the years 1865 to 1868.[2] Colonel Ward found that during the summer six months a shallow

[1] MONTHLY WEATHER REVIEW, July, 1930, vol. 58, pp. 282–283.

[2] British Rainfall, 1874, pp. 25–34.

funnel gage (of copper) and a Snowdon funnel gage (of japanned iron) gave almost identical totals, while during the winter the former gave 0.136 inch more per month. The annual total was about 30 inches. During March and April the shallow-funnel gage gave on the average 0.027 inch more per month, during the five summer months 0.035 inch less, and during the remaining winter months as much as 0.150 inch less. Apart from the winter months, when the differences were due mainly to snow, the differences were very small. The relative increase in the catch of the Snowdon gage from the spring to the summer months is associated with the general increase in the intensity of the rainfall. The Snowdon gage had therefore marked advantages in winter and in summer. There was, however, a small defect due to the larger surface of the funnel which resulted in greater loss by evaporation. This was apparent only in March and April, when showers alternating with sunshine are a feature of the weather of the British Isles. Symons was satisfied that the advantages of the Snowdon gage far outweighed this small defect,[3] and this conclusion has been borne out by subsequent experience.

A series of comparative readings were subsequently made by Colonel Ward at Rossiniere, Switzerland, with two copper gages with the rims 1 foot, 6 inches above the ground and 9 inches apart. On 30 days during the period October, 1873, to February, 1875, the precipitation took the form of snow, which lay on the ground as soon as if fell. In each case the depth of snow was less than would fill the deep funnel. On these occasions independent estimates of the precipitation were made by inverting the funnel over undrifted snow and measuring in the ordinary way after melting. The comparative readings for these days were: Shallow-funnel gage, 2.67 inches; Snowdon funnel, 5.56 inches; and the independent methods, 5.43 inches.[4] It was concluded that good estimates of snowfall could be made by the use of the Snowdon funnel gage, and that serious losses resulted with the shallow-funnel gage.

Among the numerous experiments with different types of gages carried out in the British Isles, no other comparative readings appear to have been made with funnels of depths other than those already quoted.[5] Reference should, however, be made to the experiments recently carried out by Mr. A. J. Bamford in Ceylon, using deep-funnel and shallow-funnel gages.[6] These experiments were made with special reference to losses by evaporation and to the use of bottles in gages, and they confirm in general the results already given.

In the experiments made in the British Isles using funnels of different depths, the differences in the catch have not been correlated directly with the strength of the wind, as in America.[7] As a matter of fact some of the largest differences in the catch occurred with high wind, but in general there was little correlation between the differences and the strength of the winds. Possibly this is due to the gages in the British Isles generally being in a reasonably sheltered site, since the standard height of the rim of the gage is 1 foot above the ground.

[3] British Rainfall, 1874, pp. 39–40.
[4] See British Rainfall, 1874, face p. 29.
[5] A summary of the experiments made in the British Isles is given in the article on "The Development of Rainfall Measurement in the Last Forty Years," by Dr. H. R. Mill, British Rainfall, 1900, pp. 23–41, although curiously the question of the depth of the vertical funnel is not mentioned.
[6] The Meteorological Magazine, 1930, pp. 81–87.
[7] MONTHLY WEATHER REVIEW, July 1930, vol. 58, pp. 282–283.

EARLY OPENING OF THE NEW YORK STATE BARGE CANAL

By J. H. SPENCER

[Weather Bureau Office, Buffalo, N. Y.]

The New York State Barge Canal was officially opened this year on April 6, reported to be the earliest in 103 years. The steamer *William Hengerer* and three barges left Buffalo for New York with bonded wheat on the 7th.

There was practically no ice in Lake Erie after March 29. Navigation opened at Buffalo on April 3, with the arrival of the freighter *Coralia* from Detroit loaded with automobiles. The opening of navigation this year was 12 days earlier than the average.

These events reflect the mildness of the winter in this section of the country.

"MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION, 1910

Reviewed by KATHERINE B. CLARKE

(Report on the scientific results of the *Michael Sars* North Atlantic deep-sea expedition, 1910. Edited by Sir John Murray and J. Hjort. Vol. I, Deposit Samples by J. Chumley, pp. 1–12; Physical Oceanography and Meteorology, by B. Helland-Hansen, text pp. 1–115, tables and plates pp. 1–102. Published by the Bergen Museum, Bergen, Norway, 1931.)

This volume is the first in a series on the scientific results of the *Michael Sars* expedition, a series which promises to be an exceedingly valuable contribution to the development of oceanography and associated sciences. Planned chiefly as a biological survey of the North Atlantic, a gratifying amount of geophysical and meterological data of real value was also obtained. Few persons are better qualified by knowledge and experience to write the discussion of these data than the eminent Norwegian oceanographer, Helland-Hansen.

The section on physical oceanography and meteorology has two major divisions, the text and the tables and plates. The text is further outlined in 10 chapters which cover the following topics: Introduction, sea surface and air, subsurface temperatures, salinities and densities (methods), local variations in general, short-period oscillations, the temperatures in the sea, salinities in the North Atlantic, stability, dynamics of the sea, and current measurements. The text is followed by an ample bibliography.

The chief interest from a meteorological viewpoint lies in the discussions of sea and air temperatures, the interaction of ocean and atmosphere, and diurnal, seasonal, and annual variations. Observations were made from June 3 to August 15, 1910. For purposes of statistical compilation these are divided into four series. On Deutsche Seewarte synoptic charts for each day of the cruise the position of the *Michael Sars* is shown. Accompanying graphs give for each day the meteorological conditions observed on the ship.

A very conspicuous positive correlation between surface temperatures and surface salinity was found. Regional variations were the chief cause for great variations in mean surface temperature. The daily period of surface temperature was not as evident as might be expected, but correlated closely with the amount of cloudiness, being more prominent with slight than with extensive cloudiness. A conclusion previously expressed by Helland-Hansen and Nansen, that variations in surface temperature are primarily the result of displacement of the surface

layers and that the warming and cooling effect of the air upon the sea is of secondary importance, has been substantiated by the results of this expedition. Mean air temperature was found to have a strong tendency to follow mean surface temperature. Only rarely was the difference between the two as much as 2° C. These differences though slight are of the utmost importance in atmospheric processes and necessitate the most careful observations of sea and air temperatures. The air was, as a rule, warmer than the sea by day and cooler by night, but 68 per cent of the averages give air temperatures lower than sea temperatures. Variations in humidity correspond closely to the variations in temperature differences between water and air. Moreover, variations in relative humidity coincide almost exactly with variations in absolute humidity.

In the study of gain and loss of heat the author reaches the same conclusions as Harvey;[1] namely, that evaporation is the chief cause for the loss of heat from the sea, excess of outward radiation, and direct convection to the air being of secondary importance; and that the stronger the heating of the surface layers the less the heating of the subsurface layers, due to greater stability and hence lessened convection to lower levels.

The study of seasonal variations was hampered by the fact that the author could find in literature only three cases where serial observations for deep offshore parts of the eastern North Atlantic have been taken at different seasons at the same geographical position. The author finds on the whole fairly good indication of "direct agreement between annual variations of the surface temperature toward the end of the winter and the temperatures for a considerable time (several months) afterward at 50 and 100 meters," p. 61.

Throughout the volume Helland-Hansen has amplified his discussion with results of his other observations, particularly those made in the North Atlantic in collaboration with F. Nansen. It is regrettable that the publication of results of such expeditions are so delayed. Such delays may only be compensated for by thorough and careful studies of results, such as are exhibited in this publication. The whole volume serves to emphasize the necessity for cooperation between investigators in physical oceanography and meteorology and for the collection of more detailed and accurate marine meteorological data.

[1] Harvey, M. A. Evaporation and Temperature Changes in the English Channel J. Marine Biol. Assoc., v. 13, pp. 67.8-692, 1925

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Ångström, Anders.
Das Ångström-Pyranometer, Type 1930. p. 526–534. figs. 24 cm. (Strahlentherapie, 39. Bd. (1931).)

Bider, Max.
Ergebnisse der Beobachtungen mit dem Davoser Frigorimeter in Basel. p. 541–564. figs. 24 cm. (Strahlentherapie, 39. Bd. (1931).)

Bouasse, H., & *others*.
Tourbillons, forces acoustiques, circulations diverses. Tome 1. Paris. 1931. xxiv, 422 p. figs. 25½ cm.

Davos. Physikalisch-meteorologisches Observatorium.
Neukonstruktion des "Davoser Frigorimeters." [Davos.] 1931. 2 p. illus. 34½ cm. [Manifolded.]

Field, R. H.
Aneroid barometer and altimeter, their characteristics and use in mapping. With an appendix: The field use of the aneroid barometer, by G. C. Cooper. Ottawa. 1931. 36 p. illus. 25 cm. (Canada, dept. inter. Topographic survey. Bul. no. 63.)

Ginestous, G.
Récupération de l'humidité atmosphérique. Alger. 1929. 7 p. 24½ cm. (Extr.: Rev. agric. de l'Afrique du Nord.)

Kirby, Harold Lewis.
Analysis of meteorology as related to the operation of aircraft. Los Angeles. [c1930.] 120, 14 p. front. illus. diagrs. 26½ cm.

McAdie, Alexander.
Clouds and the airman. p. 49–59. illus. 30 cm. (Nat. aeron. mag. Dec. 1930.)

Sievert, Otto.
Wetterkunde. Eine Anleitung zu Wetterverständnis und Wettervoraussage. Dritte vermehrte Aufl. Berlin. [1930.] 168 p. figs. plate (fold.). 21½ cm.

Talman, Charles Fitzhugh.
Realm of the air; a book about weather. Indianapolis. [c1931.] x, 318 p. front. plates. 23 cm.

Vallaux, Camille.
Les dérives antarctiques en surface et en profondeur. Monaco. n. d. 16 p. figs. 25½ cm. (Bull. de l'Inst. océan., No. 567. 10. fév. 1931.)

Van Orman, W. T.
Preliminary meteorological survey for airship bases on the middle Atlantic seaboard. n. p. 1931. v. p. plates. 28½ cm. (For International Zeppelin transport corporation, 52 Wall St., New York City.) [Typewritten.]

Wagner, A.
Klimatologie der freien Atmosphäre. Berlin. 1931. 70 p. figs. 27 cm. (Handbuch der Klimatologie. Bd. I, Teil F.)

Waitz, Karl.
Die kosmischen Ursachen des Wetters. Leipzig. [c1930.] vii, 95 p. figs. 23½ cm.

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS OBTAINED DURING APRIL, 1931

By HERBERT H. KIMBALL

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, REVIEW, p. 41.

Table 1 shows that solar radiation intensities averaged below the normal intensities for April at all three stations. At Madison, Wis., on the 10th a high wind caused a dust storm of unusual density. The radiation intensity at normal incidence was reduced from 1.20 at 9:30 a. m., with air mass 1.5, to 0.141 at 2:07 p. m., with air mass 1.45. Skylight polarization, at 3:44 p. m., with the sun 30° above the horizon (m=2.0) was less than 20 per cent, indicating that the depletion was due to reflection from rather coarse particles. The visibility, according to Weather Bureau officials at Madison, was only 3 miles.

Table 2 shows a deficiency in the total radiation received on a horizontal surface as compared with the normal amount for April at La Jolla and Fresno and an excess at all other stations for which normals have been computed.

Skylight polarization measurements obtained on 11 days at Madison, give a mean of 55 per cent and a maximum of 66 per cent on the 29th. At Washington, measurements obtained on four days give a mean of 59 per cent, with a maximum of 66 per cent on the 8th. These are slightly above the corresponding averages for Washington. At Madison, the values were slightly below the corresponding April averages for that station.

TABLE 1.—*Solar radiation intensities during April, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	Air mass: 75th mer. time	A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 8	3.45			1.05	1.13		1.00	0.85	0.68	0.58	4.17
Apr. 13	4.95		0.83	0.95	1.16	1.40	1.08	0.86			4.37
Apr. 14	5.79			0.73	0.85	1.07					6.56
Apr. 15	4.37			0.60	0.89	1.15	0.92	0.62	0.47		4.57
Apr. 16	6.76	0.47	0.60	0.76	0.97	1.27	0.49				4.17
Apr. 17	5.36		0.36	0.49	0.59	0.90					6.27
Apr. 20	7.04	0.62	0.75	0.88	1.00	1.39	1.01				4.17
Apr. 27	2.49	0.80	0.94	1.09							2.74
Apr. 28	3.45					1.32	1.02				3.30
Apr. 30	3.63		0.82	0.98	1.17	1.43					2.74
Means		0.63	0.72	0.84	0.97	1.24	0.92	0.78	(0.58)	(0.58)	
Departures		−0.07	−0.04	−0.05	−0.10	−0.11	−0.15	−0.11	−0.15	−0.04	

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during April, 1931*—Contd.

Madison, Wis.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	Air mass: 75th mer. time	A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Apr. 1	3.81					1.40	1.23				3.00
Apr. 4	3.30	0.54	0.66			1.39					2.87
Apr. 6	3.99				1.20	1.50	1.13				2.74
Apr. 7	3.30						0.98				4.75
Apr. 8	6.50				1.00	1.46	0.99				7.57
Apr. 10	4.95				1.13		[2] 0.26				3.15
Apr. 11	2.87		0.80	0.98	1.13	1.32					2.49
Apr. 17	5.16					1.32	1.03				4.17
Apr. 18	4.37			0.74	1.01	1.25					5.16
Apr. 24	2.62				1.06						2.49
Apr. 25	3.99			0.73	0.88						3.99
Apr. 27	2.74					1.43					2.87
Apr. 29	3.00				1.20	1.45					2.36
Apr. 30	3.15		0.76	0.87	1.06	1.35	1.01				3.30
Means		(0.54)	0.74	0.83	1.07	1.39	1.06				
Departures		−0.30	−0.18	−0.21	−0.13	−0.03	−0.13				

Lincoln, Nebr.

Apr. 1	3.81		0.75	0.94	1.17	1.44					4.37
Apr. 5	3.15					1.44	1.20	1.03	0.90	0.75	3.45
Apr. 6	3.81		0.90	1.04							4.95
Apr. 7	5.36	0.75	0.81	0.96	1.13						8.18
Apr. 8	6.76			1.05	1.21	1.43					5.56
Apr. 10	4.17	0.40	0.53	0.69	0.86						3.99
Apr. 11	6.27		0.83	0.96	1.13	1.30					6.02
Apr. 22	3.15	0.64	0.73	0.85	1.07	1.27					3.30
Apr. 26	3.15	0.72	0.86	0.93	1.12						3.45
Apr. 27	3.63		0.72	0.94	1.10	1.38	1.11	0.93	0.75		3.15
Apr. 28	6.76		0.75	0.90	1.09						5.79
Means		0.63	0.76	0.93	1.10	1.38	(1.16)	(0.98)	(0.82)	(0.75)	
Departures		−0.09	−0.07	−0.05	−0.10	−0.06	−0.01	±0.00	−0.03	+0.03	

[2] Not included in means.

TABLE 2.—*Total solar radiation (direct+diffuse) received on a horizontal surface*

[Gram calories per square centimeter]

Week beginning	Average daily totals: Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 2	248	461	400	373	241	472	263	562	524	400	442	379
Apr. 9	552	422	487	380	461	500	476	495	572	438	349	244
Apr. 16	503	332	468	251	463	556	409	621	623	402	454	388
Apr. 23	483	516	428	263	267	496	293	647	524	339	442	380
	Departures from weekly normals											
Apr. 2	−131	+73	−25	+81	−67	+72	−25	+36	−8	−22		
Apr. 9	+144	+20	+66	+64	+123	+57	+96	−44	+4	+3		
Apr. 16	+84	−64	+35	−55	+122	+78	+67	+49	+36	−30		
Apr. 23	+57	+82	−30	−60	−84	−28	−43	+29	−69	−80		
Accumulated departures on Apr. 29	+579	−2,121	−679	−588	+1,204	[1]+2,863	−514	+1,773	+238	−763		

[1] Records for February missing.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1931	h m	°	°	°			
Apr. 1 (Mount Wilson)	12 50	−79.0	169.6	−2.0	138		
		−22.0	226.6	+8.0		44	
		+32.0	280.6	−9.0	149		
		+58.0	306.6	+10.0	7		
		+75.0	323.6	−17.0		126	464
Apr. 2 (Naval Observatory)	12 20	−63.0	172.7	0.0	46		
		−5.0	230.7	+9.5		15	
		+47.0	282.7	−8.0	77		138
Apr. 3 (Naval Observatory)	10 52	−50.5	172.8	−1.0	123		
		+8.0	231.3	+8.0	3		
		+7.5	230.8	−8.0		12	
		+53.0	276.3	−4.0	9		
		+59.5	282.8	−9.0	46		193
Apr. 4 (Mount Wilson)	9 45	−38.0	172.6	−2.0		125	
		+17.0	227.6	+8.0		26	
		+30.0	240.6	−7.0		8	
		+67.0	277.6	−3.0		12	
		+71.0	281.6	−7.0	26		197
Apr. 5 (Yerkes Observatory)	11 43	−62.2	134.2	+5.4	22		
		−31.4	165.0	−2.9	9		
		−23.1	173.3	−3.0	57		
		+30.4	226.8	+6.3		36	
		+32.5	228.9	+6.6	18		
		+68.5	264.9	+5.7	31		173
Apr. 6 (Mount Wilson)	13 15	−51.0	131.4	+5.0		88	
		−10.0	172.4	−2.0		92	
		+40.0	222.4	+4.0		102	
		+46.0	228.4	+9.0	5		287
Apr. 7 (Perkins Observatory)	10 45	−35.0	135.4	+10.0		217	
		+3.0	173.4	+4.0	155		
		+51.0	221.4	+7.0		186	558
Apr. 8 (Naval Observatory)	11 14	−70.0	87.1	+3.0	9		
		−22.0	135.1	+5.0		216	
		+13.0	170.1	−3.0		139	
		+66.0	223.1	+2.0		123	487
Apr. 9 (Naval Observatory)	11 13	−70.0	73.9	+5.0	15		
		−10.0	133.9	+4.5		170	
		+28.0	171.9	−3.0		154	
		+78.0	221.9	+3.0		46	385
Apr. 10 (Naval Observatory)	11 14	+3.0	133.7	+5.0		216	
		+22.0	152.7	−3.5		31	
		+41.0	171.7	−3.0		123	370
Apr. 11 (Perkins Observatory)	14 0	−60.0	56.0	+10.0		124	
		+21.5	137.5	+12.0		124	
		+56.0	172.0	+2.0	124		372
Apr. 12 (Naval Observatory)	11 12	−65.0	39.3	+22.0		77	
		+21.0	125.3	+7.0		154	
		+33.0	137.3	+3.5		31	
		+69.0	173.3	−3.0	46		308
Apr. 13 (Naval Observatory)	11 15	−50.0	41.1	+22.0		46	
		−37.5	53.6	+7.0		139	
		+85.0	176.1	−3.0	31		216
Apr. 14 (Naval Observatory)	11 50	−61.0	16.5	+11.0		123	
		−38.0	39.5	+22.0	31		
		−22.5	55.0	+8.0		185	339
Apr. 15 (Naval Observatory)	11 17	−30.0	14.6	+10.0		216	
		−27.0	37.6	+22.0	15		
		−20.0	44.6	+11.5	15		
		−11.0	53.6	+8.0		216	462
Apr. 16 (Naval Observatory)	11 28	−40.0	11.3	+11.0		154	
		−15.0	36.3	+25.0		31	
		+2.5	53.8	+9.0		123	308
Apr. 17 (Naval Observatory)	11 14	−23.5	14.8	+11.5		185	
		−5.0	33.3	+2.5		46	
		+16.5	54.8	+9.0		123	354
Apr. 18 (Naval Observatory)	11 14	−10.5	14.6	+11.0		123	
		+30.0	55.1	+8.5		123	246

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1931	h m	°	°	°			
Apr. 19 (Naval Observatory)	11 9	+2.0	13.9	+11.5	154		
		+43.0	54.9	+9.0	123		277
		+16.0	14.6	+11.5	154		
		+41.0	39.6	+10.0	31		
		+58.0	56.6	+8.5	154		339
Apr. 21 (Naval Observatory)	11 0	+29.5	15.1	+12.0		123	
		+57.0	42.6	+10.0		247	
		+71.0	56.6	+9.0		62	432
Apr. 22 (Mount Wilson)	9 45	+42.0	15.0	+10.5		249	
		+66.0	39.0	+8.5		295	
		+89.5	62.5	+7.0	124		668
Apr. 23 (Naval Observatory)	11 13	−14.0	305.0	+15.0		62	
		+55.0	14.0	+11.5		123	185
Apr. 24 (Naval Observatory)	11 27	−80.0	225.7	+8.0	15		
		+0.1	305.8	+16.0		62	
		+68.0	13.7	+10.0	93		170
Apr. 25 (Yerkes Observatory)	15 51	−59.6	230.4	+4.4		8	
		+12.1	302.2	+14.1	16		
		+14.0	304.1	+13.9		4	
		+15.8	305.9	+14.3	8		
		+16.9	307.0	+14.8	25		61
Apr. 26 (Naval Observatory)	14 20	−48.0	229.7	+4.0	15		
		+27.5	305.2	+15.0		93	
		+30.0	307.7	−7.0	9		117
Apr. 27 (Naval Observatory)	11 22	−38.0	228.1	+5.0	31		
		+38.0	304.1	+17.5		62	93
Apr. 28 (Naval Observatory)	11 20	−23.0	229.9	+5.0	31		31
Apr. 29 (Naval Observatory)	11 24	−10.0	229.6	+5.0	15		
		+33.0	272.6	+14.0	19		34
Apr. 30 (Naval Observatory)	11 22	+4.0	230.4	+5.0	15		
		+48.0	274.4	+15.0		62	77
Mean daily area for April							278

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR APRIL, 1931 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

April, 1931	Relative numbers	April, 1931	Relative numbers	April, 1931	Relative numbers
1	*d* 34	11	*d* 36	21	Wc 38
2	32	12	36	22	41
3	29	13	*a* 44	23	27
4		14	38	24	Mc 29
5	Ec 25	15	37	25	37
6	31	16	*a* 31	26	21
7	*a* 40	17	41	27	19
8	44	18	22	28	14
9	45	19	*a* 20	29	Wc 17
10	*a* 29	20	20	30	18

Mean: 29 days=30.9.

[1] Dependent alone on observations at Zurich and its station at Arosa.
a=Passage of an average-sized group through the central meridian.
c=New formation of a center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

Free-air temperatures during April were moderately above normal at the northern stations, viz, Ellendale and Royal Center, and below normal at the more southern stations. (Table 1.)

Relative-humidity departures were small and variable in most cases.

Vapor-pressure departures were mostly negative.

In Table 2 are shown the mean free-air temperatures and relative humidities at the Naval Air stations, and it will be noted that the agreement with the kite data is close when geographical location is considered.

Free-air resultant winds at the 3,000 meter level were predominantly westerly. The highest resultant velocities occurred in the northern and northeastern sections of the country.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during April, 1931*

TEMPERATURE (°C.)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	12.9	−2.7	13.8	−2.5	6.4	+0.8	14.2	−3.8	9.5	−0.9
500	12.0	−1.9	12.3	−1.9	6.4	+1.2	13.0	−2.7	8.7	+0.8
1,000	9.5	−2.0	9.7	−1.8	5.6	+2.9	11.1	−2.9	6.7	+1.2
1,500	6.9	−2.5	6.9	−1.8	2.5	+2.0	10.4	−2.4	3.7	+0.4
2,000	4.4	−2.7	4.3	−1.6	−0.6	+1.5	8.6	−2.1	1.1	+0.2
2,500	1.6	−2.6	1.3	−2.2	−4.0	+0.9	5.9	−2.2	−1.1	+0.6
3,000	−1.2	−2.3	−1.7	−2.5	−7.2	+0.7	3.1	−2.1	−3.1	+1.2
4,000	−7.5	−2.5	−7.7	−3.2	−13.6	+0.4	−2.1	−1.0	−7.7	+1.8
5,000	−11.7	−1.0	------	------	−20.8	−1.0	------	------	−12.7	+2.6

RELATIVE HUMIDITY (%)

Surface	73	+9	70	+7	63	−2	74	+1	66	+1
500	68	+5	66	+4	61	−3	66	−5	62	−3
1,000	62	+2	61	0	53	−7	60	−2	59	−3
1,500	60	+5	57	−3	53	−4	51	+2	62	+3
2,000	57	+7	54	−3	51	−4	48	+5	61	+4
2,500	54	+5	53	+1	50	−4	52	+11	59	+7
3,000	54	+6	53	+3	51	−3	40	0	55	+5
4,000	52	+7	68	+20	52	−4	------	------	46	−3
5,000	46	0	------	------	52	−2	------	------	51	+7

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during April, 1931*

VAPOR PRESSURE (*mb.*)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	11.16	−0.68	11.28	−0.58	5.73	−0.11	12.16	−3.28	7.81	−0.82
500	9.78	−0.62	9.60	−0.73	5.62	−0.06	10.17	−2.90	7.05	−0.31
1,000	7.65	−0.74	7.45	−1.14	4.62	+0.09	8.28	−1.86	5.94	−0.05
1,500	6.16	−0.51	5.74	−1.20	3.70	0.00	6.57	−0.58	4.95	+0.01
2,000	4.90	−0.20	4.47	−0.79	2.84	−0.13	5.43	+0.08	3.99	−0.01
2,500	3.69	−0.40	3.63	−0.30	2.13	−0.27	4.74	+0.48	3.19	+0.14
3,000	2.88	−0.39	2.98	−0.05	1.70	−0.23	2.80	−0.63	2.51	+0.10
4,000	1.53	−0.48	3.28	+1.28	0.93	−0.35	------	------	1.29	−0.34
5,000	0.73	−0.62	------	------	0.63	−0.15	------	------	0.75	−0.37

TABLE 2.—*Free-air obtained by airplanes at naval air stations during April, 1931*

Altitude (meters) m. s. l.	Temperature (°C.)				Relative humidity (%)			
	Hampton Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Hampton, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	12.1	15.2	19.1	10.8	64	80	65	64
500	10.6	14.5	16.3	9.1	53	70	70	57
1,000	7.9	12.4	15.7	7.4	50	61	57	55
2,000	2.9	7.7	12.0	2.5	47	52	36	53
3,000	−3.0	2.2	5.6	−1.8	51	50	29	56
4,000	------	−4.8	------	------	------	65	------	------

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during April, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (127 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 87 E	0.7	S 66 E	0.6	S 8 W	1.4	N 75 W	3.6	N 50 W	0.5	S 28 E	0.9	N 21 W	0.4	N 75 W	1.7	S 87 W	1.4	N 37 W	0.6	N 55 E	1.4	N 50 E	0.7
500	------	----	S 27 E	6.1	S 42 W	3.2	------	----	N 65 W	2.9	S 14 E	3.7	N 74 W	2.2	N 86 W	1.9	------	----	S 8 W	0.3	S 87 E	3.7	S 75 E	1.7
1,000	------	----	S 4 E	4.8	S 76 W	4.0	------	----	N 55 W	5.4	S 44 E	2.0	N 75 W	3.2	S 79 W	3.6	S 72 W	4.3	S 33 W	1.0	S 53 E	2.9	N 38 E	1.0
1,500	------	----	S 10 E	2.6	N 52 W	5.3	------	----	N 64 W	6.3	S 26 E	0.5	N 67 W	3.8	N 83 W	4.2	S 86 W	6.2	S 82 W	1.0	N 89 E	1.4	N 27 E	0.5
2,000	S 31 W	1.8	S 3 E	2.2	N 45 W	5.4	N 76 W	5.7	N 69 W	8.7	N 45 W	0.1	N 72 W	3.3	N 77 W	5.7	N 88 W	5.9	N 77 W	4.0	N 42 W	0.5	N 70 W	1.0
2,500	S 82 W	2.7	S 75 W	1.7	N 49 W	8.0	N 68 W	8.5	N 59 W	10.2	N 28 W	1.5	N 79 W	5.5	N 68 W	6.5	N 90 W	5.6	N 80 W	4.5	N 85 W	2.2	N 71 W	3.0
3,000	N 85 W	5.3	N 86 W	2.6	N 44 W	7.8	N 60 W	7.6	N 66 W	6.8	S 65 W	1.2	N 60 W	6.4	N 60 W	8.9	N 80 W	4.9	N 85 W	4.7	S 89 W	3.2	N 60 W	3.2
4,000	N 83 W	7.1	N 61 W	10.1	N 78 W	6.5	N 70 W	9.0	------	----	------	----	N 61 W	9.0	N 61 W	10.7	N 59 W	4.1	N 88 W	7.8	N 80 W	6.3	N 51 W	7.7
5,000	N 88 W	4.6	------	----	------	----	N 81 W	7.9	------	----	------	----	N 55 W	9.8	N 76 W	12.5	------	----	N 79 W	10.2	S 76 W	4.8	------	----

Altitude (meters) m. s. l.	Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		Modena, Utah (1,665 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma, City, Okla. (392 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 (meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	N 4 W	0.9	N 10 E	0.7	S 70 W	2.0	N 54 E	0.8	S 56 E	0.4	S 20 E	0.7	S 85 E	0.6	S 83 E	2.5	S 42 E	2.6	N 18 E	0.5	S 52 E	0.9	N 64 W	0.5
500	N 6 W	0.7	N 86 W	0.9	------	----	N 73 E	2.2	N 74 W	1.0	S 16 E	1.7	S 29 W	0.8	S 77 E	2.3	------	----	S 41 W	0.9	S 2 W	2.6	N 87 W	7.1
1,000	N 34 E	0.2	N 59 W	1.8	------	----	N 65 E	1.1	N 36 W	2.7	S 28 W	2.4	S 82 W	3.7	S 19 W	1.0	------	----	N 82 W	4.5	S 8 E	3.1	N 68 W	4.1
1,500	S 23 E	2.0	N 43 W	2.8	------	----	N 54 W	1.0	N 70 W	2.6	S 59 W	0.9	S 88 W	5.2	S 58 W	2.1	S 23 E	2.7	N 64 W	6.6	S 5 W	2.3	N 63 W	7.5
2,000	S 11 W	2.0	N 48 W	4.7	S 51 W	0.3	N 68 W	2.3	S 87 W	1.6	N 79 W	1.7	N 84 W	4.9	S 39 W	2.5	S 36 W	2.2	N 57 W	7.9	S 40 W	1.8	N 67 W	7.3
2,500	S 31 W	1.5	N 66 W	4.8	S 43 W	1.1	W	2.7	S 84 W	2.7	N 68 W	3.5	N 56 W	5.5	S 36 W	2.6	S 70 W	2.7	N 56 W	8.0	S 72 W	3.9	N 65 W	8.5
3,000	S 49 W	1.8	N 82 W	6.3	S 70 W	2.0	S 87 W	3.5	N 80 W	3.9	S 88 W	4.9	N 45 W	4.7	S 53 W	3.4	S 89 W	3.9	N 47 W	8.4	S 85 W	5.7	N 62 W	9.8
4,000	S 85 W	1.5	------	----	N 83 W	5.7	S 78 W	7.1	N 81 W	1.0	------	----	N 80 W	4.9	S 83 W	3.8	N 79 W	5.6	N 48 W	8.7	------	----	N 57 W	11.4
5,000	------	----	------	----	N 70 W	6.9	N 82 W	9.5	------	----	------	----	N 68 W	9.5	------	----	N 79 W	8.8	N 52 W	8.2	------	----	------	----

TABLE 4.—*Observations by means of kites, captive and limited height sounding balloons during April, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	3,247	2,576	3,197	2,049	3,315
Maximum altitude (meters), m. s. l., reached	[1] 5,314	4,771	4,993	4,702	[1] 5,712
Number of flights made	32	31	30	20	31
Number of days on which flights were made	29	30	29	20	30

[1] Limited-height sounding balloon observation.

In addition to the above, there were approximately 176 pilot balloon observations made daily at 60 Weather Bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

During April the temperature in the northern and western sections of the country was above normal, while in the South from the Great Plains eastward to the Atlantic it was cool. The lowest temperature occurred during the early part of the month, and freezing weather was recorded in every State except Florida.

Precipitation for the month was below normal over much of the country. The greatest deficiencies occurred from the lower Mississippi Valley eastward, and in the western Lake region, the northern Great Plains and northern California, with some rather large areas receiving less than half the average for the month. On the other hand, precipitation much above the normal was noted in southern California and eastward to western Texas and New Mexico, some stations reporting the heaviest precipitation of record for April. Likewise the upper Ohio Valley, much of New York, Pennsylvania, the Virginias and Carolinas and the Florida Peninsula received more than normal.

TEMPERATURE

The general temperature situation in April was decidedly like that in March, each month averaging warmer than normal throughout northern and far western sections but cooler than normal elsewhere. However, different portions of April showed decided contrasts.

The opening week was generally colder than normal, but was warmer in the extreme Northeast, the upper Missouri Valley and the far West. Thereafter, for a fortnight, nearly all the country experienced warm weather, especially the north-central portion; but much of the Gulf section and part of the far Northwest were slightly cooler than normal.

The final decade of April was colder than normal in nearly all the country, particularly from the western Plains eastward to the Appalachian Mountains; but the Pacific States and much of the Plateau region and Florida averaged warmer than normal.

April averaged almost 5° colder than normal in Texas, where it was slightly colder than the coldest previous April in the 40-year period of State-wide record, and generally from central New Mexico and western Kansas eastward to the south Atlantic and southern middle Atlantic coast it was somewhat colder than normal. In the northern portion of the country and west of the Continental Divide, the month averaged warmer than normal, the greatest excesses, over 3° per day, being noted in Minnesota and California. At Los Angeles and Sacramento, Calif., it was the hottest April of record, and very nearly the hottest at Yuma, Ariz.

The highest temperatures were recorded usually during the period from the 8th to the 19th, but in the far Northwest and part of the south Atlantic area during the last five days of the month. A few stations in Arizona and California recorded temperatures above 100°, while in about half of the States the marks were 90° or higher. Most of the northern border, Ohio Valley, and Atlantic States recorded no marks quite as high as 90°.

The lowest temperatures occurred usually during the opening week, save in California, part of the Plains, and a few eastern States at various dates during the final decade. Florida, which recorded 33° at one station, was the only State entirely without freezing weather, but only in Michigan, Colorado, Wyoming, Montana, and Idaho, were marks below zero reached at any stations.

PRECIPITATION

The first week of April brought considerable rain to Washington and portions of the States adjoining, also in the eastern half to many portions of the Atlantic and East Gulf States and the upper and middle Ohio Valley. The second and third weeks were less rainy, viewing the country as a whole; but the far Northwest had moderate amounts till about the 18th, while from northern Arkansas to southern Minnesota most counties had considerable rain and the greater part of the Florida peninsula was visited by heavy downpours about the 15th.

From the 22d onward the rainfall was mainly more plentiful and more widely distributed, although the far Northwest and many north-central districts had either none or very little. Considerable portions of southern California and Arizona received heavy rains for the region and the time of year. The Rio Grande Valley and most of the middle Plateau and Rocky Mountain regions had much precipitation, likewise a broad area from Texas northeastward to and including the Appalachian region, the Ohio Valley, and the lower Lake region.

The month's precipitation was less than normal in about three-fourths of the States, yet there were many favorable features. The largest amounts, slightly over 10 inches, were reported from a few stations in Washington and Florida. Practically throughout the Ohio Valley, Virginia, Maryland, and New Jersey there was at least 1.5 inches at every station, and in a large part of the Ohio Valley and the vicinity of Lake Erie, the monthly precipitation was greater than normal for the first time in more than a year. Most of Virginia and of the central and western portions of the Carolinas had more rain than normal, and almost all of the Florida Peninsula a marked excess.

West of the Mississippi River there was more precipitation than normal in considerable portions of Arkansas, Oklahoma, and Kansas, almost throughout the drainage area of the Rio Grande, and in the southern portions of Arizona and California. At El Paso, Tex., 2.24 inches fell, more than eight times the normal April quantity, and 160 per cent of the greatest previous April fall in a record of more than 50 years. Los Angeles measured 3.02 inches, practically three times the normal, all of it within the space of six days, 22d to 27th, and almost three-fifths of it within 24 hours.

The inset on Chart V shows the departure from the normal for the month. As there shown the precipitation was considerably less than normal in the vicinity of the lower Mississippi River and in the upper Lake region and thence westward to northwestern Nebraska, the northeasternmost part of Wyoming, and the central portion of Washington. In the northern half of California the precipitation was decidedly deficient, save in the region of the Sierra Nevada Mountains.

SNOWFALL

The April snowfall was considerable over most portions of New York and eastern Ohio, in western and northern Pennsylvania, and the mountainous portions of Maryland, the Virginias, and North Carolina. On the other hand, the upper Lake region had comparatively little, and the greater part of the upper Mississippi and lower Missouri Valleys had either none whatever or too little to be measured.

In northwestern Kansas, the western half of Nebraska and much of South Dakota there was considerable snow, chiefly after the 20th of the month.

In the elevated portions of the regions near or to westward of the Continental Divide, the snowfall was mainly much below normal in the northern area and somewhat below in the southern. Certain districts in about latitudes 37° to 43° had considerable snowfall, especially the Sierra Nevada region.

SUNSHINE AND RELATIVE HUMIDITY

Rather abundant sunshine prevailed generally during the month in the northern and central areas from the Great Plains eastward to the Atlantic and in the Pacific regions from southern Washington to central California. On the other hand, the sunshine was deficient throughout much of Texas, Oklahoma, eastern Colorado, and New Mexico. Elsewhere it was generally near or slightly below the normal. The relative humidity was above the average from southern Arizona eastward to central Texas and Oklahoma. The plus departures were rather large in some of the areas, as would be expected from the large amount of precipitation received in those regions. Elsewhere the relative humidity was generally near or slightly below the normal.

SEVERE LOCAL STORMS, APRIL, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Cattaraugus, Allegany, and Wyoming Counties, N. Y.	2					Snow	Trees, telephone and power lines considerably damaged.	Official, U. S. Weather Bureau.
Pittsburgh, Pa., and vicinity	3-4					Thunderstorm and heavy rain.	25 persons marooned on island; basements flooded; other property damage.	Do.
Havre, Mont., and vicinity	7-9					Wind	Minor damage to windows and signs; considerable loss by blowing soil.	Do.
Clark and Comanche Counties, Kans.	15	2-4 p. m.	9 mi.			Heavy hail	Character of damage not reported; path 19 miles long.	Do.
Edwards County, Kans.	15	4 p. m.	5 mi.		$10,000	do	Character of damage not reported; path 10 miles long.	Do.
Pawnee County, Kans.	15	P. m.				do	Damage heaviest near Rozel; character not reported.	Do.
White Signal, N. Mex.	16	1-1:30 p. m.	1,760-3,520			do	Roofs considerably damaged; gardens destroyed.	Do.
Adair County, Iowa	18	4:30-5:30 p. m.			10,000	Wind, hail and probably a tornado.	Character of damage not reported	Do.
Dallas County, Iowa	18	P. m.	1,760		6,000	Hail	Buildings and crops damaged; path 3 miles long.	Do.
Lawrence, Monroe, Pike, and Wayne Counties, Miss.	19	P. m.				do	Considerable damage, character not reported.	Do.
Indianapolis, Ind. (7 miles south of).	20	A. m.				Thunderstorm	3 horses killed; truck and quantity of hay, feed, and other grains destroyed.	Do.
Washington and Oregon	21-23					Wind and dust	Severe injury to fruit blooms, vegetables, and truck; grains blown out; timber and communication lines prostrated.	Do.
Lynchburg, Va.	22	12:15-12:30 p. m.	50		4,500	Tornado	Roofs blown from 24 houses; 1 small building demolished.	Do.
Utah (northern)	22-23					Wind and sand	Overhead wires and trees blown down; 11 freight cars blown from track; many residences damaged and several small buildings wrecked; crops injured; traffic delayed.	Do.
Palisade, Vineland, and Upper Orchard Mesa, Colo.	24	12.1 p. m.			12,000	Hail	Apricots considerably damaged; other fruits slightly injured.	Do.
Hosston to Gigsland, La.	25	9 p. m.	2-6 mi.		10,000	Thundersquall, hail, and tornadic wind.	Buildings and crops damaged; much replanting required; path 55 miles.	Do.
Marietta to Kildare, Tex.	25		3,520			Hail	Corn and fruit severely hurt	Do.
Belen, N. Mex.	27	3:30 p. m.			2,000	do	Roofs, orchards, and gardens damaged	Do.
El Paso, Clint, and Sanderson, Tex.	28-29		1,760			Thunderstorm and hail.	Young crops destroyed; auto tops pierced; livestock killed; path 315 miles long.	Do.
Little Rock, Ark.	30					Severe thunderstorm.	Small buildings floated from foundations; plate glass broken.	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES

There were more overflows in April, 1931, than in any other month since June, 1930, but those east of the Rocky Mountains were of minor importance.

Mild weather and rain near the middle of the month produced stages that were slightly above bankful in the Connecticut River, the Chenango (in New York) and the upper Susquehanna (in New York). There was no damage attendant upon the overflows. Some merchandise, valued at $25,000, in Hartford, Conn., was saved by being moved to a safe place before the overflow arrived.

Bankful stages were reached by some of the rivers in eastern North and South Carolina, western Alabama, northern Missouri, western Pennsylvania, and southeastern Ohio. The overflows were slight and the reported property damage was small, but three persons were drowned in Ohio.

Roads were damaged to an indeterminate extent by Pawnee Creek, in Pawnee County, Kans.

Floods in Oregon and Washington were of greater consequence than any of those east of the Rocky Moun-

tains, but information in regard to their extent and intensity is still incomplete. A discussion of them will appear in a later copy of the REVIEW.

River stages that were unprecedentedly or unusually low for April prevailed in all of the Mississippi System, except in the Ohio Basin.

Table of flood stages in April, 1931

[All dates in April unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE					
	Feet			*Feet*	
Connecticut: Hartford, Conn	16	12	16	17.9	13
Chenango: Sherburne, N. Y	8	10	11	8.8	11
Susquehanna: Oneonta, N. Y	12	11	13	14.5	11
Roanoke:					
Weldon, N. C	30	7	9	32.8	8
Scotland Neck, N. C	23	7	11	25.7	9
Williamston, N. C	7	5	18	8.6	13
Neuse:					
Neuse, N. C	15	8	9	15.8	9
Smithfield, N. C	14	7	11	15.8	9
Cape Fear: Elizabethtown, N. C	22	8	10	25.7	9
Peedee: Mars Bluff Bridge, S. C	17	10	11	17.4	11
Santee:					
Rimini, S. C	12	2	11	14.0	6
Ferguson, S. C	12	5	12	12.6	10
EAST GULF OF MEXICO DRAINAGE					
Tombigbee: Lock 10, Demopolis, Ala	39	6	10	42.3	8
MISSISSIPPI SYSTEM					
Missouri Basin					
	Feet			*Feet*	
Grand: Chillicothe, Mo	18	21	22	21.9	21
Ohio Basin					
Kiskiminitas: Saltsburg, Pa	8	4	4	8.8	4
Allegheny: Lock 5, Freeport, Pa	24	4	4	24.7	4
Hocking: Athens, Ohio	17	5	5	17.4	5
Scioto: Larue, Ohio	11	4	4	11.1	4
Holston, North Fork: Mendota, Va	8	5	5	10.0	5
WEST GULF OF MEXICO DRAINAGE					
Trinity: Dallas, Tex	28	1	2	31.7	1
Rio Grande: Del Rio, Tex	10	29	29	10.1	29
PACIFIC SLOPE DRAINAGE					
Columbia Basin					
Willamette, Coast Fork: Saginaw, Oreg	9	1	1	10.4	1
Long Tom: Monroe, Oreg	8	Mar. 31	7	12.4	2
North Santiam: Mehama, Oreg	15	do	1	16.0	1
South Santiam: Waterloo, Oreg	20	do	1	21.0	1
Santiam: Jefferson, Oreg	10	do	2	17.5	1
Yamhill: McMinnville, Oreg	35	1	3	41.2	1
Willamette:					
Eugene, Oreg	12	1	1	13.0	1
Harrisburg, Oreg	10	Mar. 31	3	15.0	1
Albany, Oreg	20	2	3	22.9	3
Salem, Oreg	20	1	2	23.3	2
Oregon City, Oreg	12	1	5	15.0	3

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The weather over the North Atlantic during April was in marked contrast to that prevailing during the previous month, which was unusually stormy with abnormal pressure distribution. On the other hand, the number of days with gales during the current month was considerably below the normal, and the gales were not reported on more than three days in any 5° square, the maximum occurring in the square between the fortieth and forty-fifth parallels and thirtieth and thirty-fifth meridians. Up to time of writing only 21 vessels have rendered storm reports indicating a wind force of 9 or over; 4 vessels reported highest force 10, and 1 force 11.

Fog was unusually prevalent over the Grand Banks, where it was reported on from 8 to 14 days. The number of days in which it occurred in other localities is as follows: Along the American coast, between the thirty-fifth and forty-fifth parallels, from 6 to 8 days; over the steamer lanes, between the tenth and fortieth meridians, from 1 to 3 days; along the European coast, from 1 to 4 days; in the Gulf of Mexico, 4 days.

In the following table giving the barometric data at a number of island and coast stations, it will be noticed that Julianehaab, Greenland, and Cape Gracias a Dios, Nicaragua, are missing. From the former station reports were received on only 15 days, and from the latter, none since April 14. According to press reports the station at Cape Gracias was attacked and dismantled by Nicaraguan insurgents. Observations were resumed on May 19, however, and the results should appear in the table for June.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean, April, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Belle Isle, Newfoundland	29.87	[1] +0.04	30.40	21st	29.34	28th.
Halifax, Nova Scotia	29.97	[2] +0.04	30.40	13th	29.56	27th.
Nantucket	30.00	[2] +0.03	30.42	13th	29.46	2d.
Hatteras	30.06	[2] +0.03	30.40	13th	29.26	1st.
Key West	30.01	[2] −0.02	30.24	7th	29.80	1st.
New Orleans	30.09	[2] +0.05	30.30	6th [3]	29.84	1st.[3]
Turks Island	30.05	[1] +0.03	30.16	4th	29.96	16th.[3]
Bermuda	30.12	[2] +0.03	30.30	4th	29.84	24th.
Horta, Azores	30.21	[1] +0.10	30.44	16th	29.80	7th.
Lerwick, Shetland Islands	29.81	[1] +0.01	30.28	19th	29.34	5th.
Valencia, Ireland	29.96	[1] +0.07	30.48	13th	29.07	24th.
London	29.88	[1] +0.01	30.29	10th	29.12	25th.

[1] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[2] From normals based on 8 a. m. observations.
[3] And on other date or dates.

Charts VIII and IX show the conditions on the 1st and 2d when there was a well-developed disturbance, central on the 1st near the Virginia Capes, the storm area that day extending south into the Gulf of Mexico.

On the 3d and 4th unusually strong northeast trade winds occurred in the vicinity of the Canal Zone, as shown by reports from the British steamship *Shirvan*, given in the table of gales. On the same date there was also a disturbance over the Azores, that reached its greatest intensity on the 4th. On the 6th and 7th a slight depression was off the American coast, between the thirtieth and fortieth parallels, and on the same date moderate gales were also reported from vessels in the middle section of the steamer lanes.

On the 8th and 9th the region between the twentieth meridian and the Azores was swept by a severe disturbance, and on the latter date the Italian steamship *Conte Biancamans*, encountered a northwest wind, force 11, as shown in table of gales.

From the 10th to the 21st moderate weather was the rule over the ocean as a whole, although on the 14th a stiff "Norther" was encountered in the Gulf of Mexico, as shown by the report from the American steamship *Alabama* in the table of gales, and on the 16th a LOW off the east coast of Newfoundland was responsible for winds of force 7 in the southerly quadrants.

On the 22d a LOW central near 35° N. and 53° W., drifted slowly northward during the next 48 hours, and moderate to strong gales occurred on the 22d in the northerly quadrants, and on the 23d and 24th in the southerly.

On the 23d a disturbance was central near 43° N. and 20° W., that increased in intensity as it moved eastward, and on the 24th northwest gales prevailed over the steamer lanes between the fifteenth and thirtieth meridians.

During the remainder of the month the weather conditions were hardly worthy of note, except that on the 27th a LOW central near Eastport, Me., was attended by moderate gales, the storm area extending as far south as the thirty-eighth parallel.

OCEAN GALES AND STORMS, APRIL, 1931

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Tatsuno Maru, Jap. S. S.	Tampa	Houston	27 48 N	84 44 W	Mar. 31	4 a. 1	Apr. 1	29.59	W	W, 8	W	W, 8	Steady.
Lotte Leonhardt. Ger. S. S.	New York	Aruba	28 21 N	73 57 W	do	7 a. 1	do	29.63	S	WSW, —	WSW	WSW, 9	S, WSW.
Persephone, Danzig M. S.	Las Piedras	Southampton	42 35 N	32 12 W	Apr. 2	11 p. 2	Apr. 4	29.92	SW	NNW, 8	NNE	N, 9	NNW, N.
Shirvan, Br. S. S.	Canal Zone	Lands End	12 12 N	76 32 W	Apr. 3	7 a. 3	Apr. 3	29.80	NE	N, —	ENE	—, 8	NE, ENE.
Prusa, Am. S. S.	Galveston	Barcelona	38 08 N	24 30 W	do	8 a. 4	Apr. 4	29.60	NNW	NNW, 9	NE	NNW, 9	NW, NE.
Stuyvesant, Du. S. S.	New York	Port au Prince.	33 46 N	74 02 W	Apr. 5	Mdt. 5	Apr. 6	29.82	WSW	SSW, 9	SW	SSW, 9	
President Wilson, Am. S. S.	Marseille	New York	40 50 N	31 50 W	Apr. 7	2 p. 7	Apr. 8	29.61	NW	NW, 5	NNW	NNW, 9	NW, NNW.
Jefferson Myers, Am. S. S.	London	Philadelphia	39 56 N	60 26 W	Apr. 8	2 p. 8	Apr. 9	29.36	SW	SW, 10	NNW	SW, 10	
Oilfield, Br. S. S.	Hull	Curacao	43 38 N	21 25 W	do	3 p. 8	do	29.30	NE	N, 10	N	N, 10	NE, NW.
Conte Biancamano, Ital. S. S.	New York	Gibraltar	37 50 N	18 40 W	do	7 p. 9	do	29.42	NW	NW, 9	NE	NW, 11	NW, NNE.
Alabama, Am. S. S.	Port Arthur	Wilmington, N. C.	26 20 N	85 40 W	Apr. 13	2 p. 14	Apr. 14	29.76	ENE	NNE, 10	NE	NNE, 10	Steady.
Excelsior, Am. S. S.	Marseille	Boston	42 57 N	58 55 W	Apr. 15	2 a. 15	Apr. 16	29.88	N	N, 7	NW	NW, 9	
Examelia, Am. S. S.	Alexandria	do	43 40 N	42 50 W	do	Mdt. 15	Apr. 17	29.55	SE	SW, 8	SW	SE, 9	S, SW.
Boniface, Br. S. S.	Para	Antwerp	50 19 N	0 51 W	Apr. 17	11 a. 18	Apr. 18	29.45	WNW	N, 9	NE	NNW, 10	NNW, NE.
Bilderdijk, Du. S. S.	Rotterdam	Boston	42 21 N	45 10 W	Apr. 22	8 a. 22	Apr. 22	29.84	ESE	ESE, 9	S	ESE, 9	ESE, S.
Jamaica Settler, Br. S. S.	London	Kingston	47 00 N	14 30 W	Apr. 23	8 p. 23	Apr. 24	29.32	WSW	WSW, 7	NW	NW, 9	WSW, WNW.
Lord Kelvin, Br. S. S.	Halifax	Cable Grounds	50 10 N	23 10 W	Apr. 22	10 a. 24	Apr. 25	29.46	W	NW, 7	NW	NW, 9	Steady.
Express, Am. S. S.	Casa Blanca	New York	38 02 N	69 06 W	Apr. 26	9 p. 26	Apr. 27	29.61	S	SW, 9	WNW	SW, 9	S, WSW.
Cingalese Prince, Br. M. S.	Naples	Boston	42 24 N	65 49 W	do	7 a. 27	do	29.63	SE	SW. 6	W	WSW. 9	S, SW.
NORTH PACIFIC OCEAN													
Stuart Dollar, Am. S. S.	Legaspi	Los Angeles	35 20 N	159 00 E	Mar. 31	8 a. 2	Apr. 2	29.49	SSE	SW, 10	SW	SW, 10	SSE-SW.
Golden Peak, Am. S. S.	Shanghai	San Francisco	36 56 N	149 18 E	Apr. 2	10 a. 2	do	29.26	WNW	WNW, 10	W	WNW, 10. NW, 9	WNW-W.
Silvercedar, Br. M. V.	Balik Papan	do	38 16 N	154 58 W	do		do						
Nevada, Am. S. S.	Portland	Yokohama	46 25 N	155 32 E	do	10 p. 2	Apr. 3	28.96	NE	NE, 8	N	N, 11	NE-N.
Grays Harbor, Am. S. S.	Tacoma	do	48 05 N	157 03 E	do	6 a. 3	Apr. 4	28.69	E	N, 10	NNW	ENE, 10	
Do	do	do	40 32 N	148 06 E	Apr. 5	3 a. 6	Apr. 6	29.61	SE	SE, 9	SSW	ESE, 9	SE-WSW.
Canad. Winner, Br. S. S.	Victoria	Panama	14 28 N	95 58 W	do	3 p. 5	do	29.97	ESE	N, 10	N	N, 11	S-NxE.
Iowan, Am. S. S.	Los Angeles	Balboa	15 10 N	96 00 W	do	—5	do	29.88	ENE	ENE, 7	N	N, 10	ENE-N.
Golden Tide, Am. S. S.	Portland	Yokohama	49 08 N	142 20 W	Apr. 6	8 a. 6	Apr. 7	29.42	WNW	WSW, —	N	WNW, 9	WNW-WSW.
Grays Harbor, Am. S. S.	Tacoma	do	38 50 N	145 20 E	do	Noon 7	Apr. 8	29.13	WSW	W, 9	NW	W, 9	S-WNW.
Stuart Dollar, Am. S. S.	Legaspi	Los Angeles	40 55 N	161 40 W	Apr. 10	11 a. 10	Apr. 11	29.43	SW	SW, 7	WNW	WNW, 9	WSW-WNW.
Chief Capilano, Br. S. S.	Port Alberni	Osaka	49 25 N	174 15 E	Apr. 11	2 p. 12	Apr. 12	28.92	SSW	WSW, 9	WNW	WSW, 9	WSW-WNW.
Canad. Seigneur, Br. S. S.	Union Bay	Yokohama	48 11 N	168 22 E	Apr. 12	4 a. 12	do	29.04	W	W, 9	W	W, 9	W-WSW.
Golden River, Am. S. S.	Hong Kong	San Francisco	46 45 N	153 40 W	Apr. 17	4 p. 20	Apr. 20	29.93	NE	NE, 7	NE	NE, 9	NNE-NE.
Emp. of Russia, Can. S. S.	Victoria	Yokohama	49 32 N	170 59 E	do	4 p. 18	do	29.35	SSW	S, 8	W	S, 10	S-SSW.
Minnesotan, Am. S. S.	Los Angeles	Balboa	14 26 N	96 42 W	Apr. 22	—22	Apr. 23	29.82	ENE	ENE, 7	N	NNE, 9	ENE-NNE.
Golden Tide, Am. S. S.	Portland	Yokohama	43 30 N	156 26 E	do	3 a. 23	Apr. 24	29.55	SSW	SW, 7	N	SSW, 10	SSW-WNW.
Do	do	do	38 51 N	146 21 E	Apr. 25	9 p. 25	Apr. 26	29.87	NNW	NNW, 10	NNW	SSW, 10	SSW-NNW.
Jeff Davis, Am. M. V.	San Pedro	Honolulu	25 08 N	148 48 W	Apr. 27	4 p. 27	Apr. 27	29.67	SW	WSW, 8	W	WSW, 8	WSW-NW.
Pres. Madison, Am. S. S.	Seattle	Yokohama	47 50 N	165 03 E	Apr. 26	6 a. 27	do	29.12	SSW	S, 8	WSW	S, 8	S-WSW.
City of Los Angeles, Am. S. S.	Los Angeles	Honolulu	29 26 N	137 05 W	Apr. 28	3 a. 28	Apr. 28	29.60	SE	SE, 9	SE	SE, 10	Steady.
Shoyo Maru, Jap. S. S.	Yokohama	Los Angeles	41 19 N	159 19 E	do	1 p. 29	Apr. 30	29.36	SE	E, 9	NE	E, 9	
Golden Star, Am. S. S.	Hong Kong	San Francisco	41 05 N	153 55 E	do	8 p. 28	Apr. 29	29.43	SE	SE, 7	NE	NE, 9	SE-NE.
Do	do	do	43 10 N	159 35 E	Apr. 30	6 p. 30	May 1	29.03	SE	SE, 8	SW	SE, 9	SE-SW.
SOUTH PACIFIC OCEAN													
Canad. Conqueror, Can. S. S.	Panama	Auckland	32 55 S	174 20 W	Apr. 9	4 a. 10	Apr. 10	29.29	NNE	NE, 10	WSW	W, 10	

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—During the early half of April, 1931, low pressure was, for the most part, well developed in northern waters, with days of greatest intensity and lowest barometer in the Aleutian region on the 4th and during the 11th to 13th. For the same 15-day period the North Pacific anticyclone was well established in its usual position except during the first three or four days. On the 16th it spread northward, enveloping the Aleutian region and the Gulf of Alaska and giving barometric readings as high as, or higher than, 30.50 inches at Dutch Harbor and Kodiak on the 18th and 19th. Thereafter the anticyclone weakened and became disrupted in area, and toward the end of the month was displaced by cyclonic conditions over most of the eastern half of the ocean, except for a considerable strip along the American coast from lower Alaska southward, where the HIGH was reorganizing and, in lower latitudes, expanding westward. At Midway Island there were no pressure readings below 30 inches until the 28th.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, April, 1931*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	30.16	+0.07	30.90	30th	29.24	13th.
Dutch Harbor [1]	29.82	+0.02	30.54	18th	28.80	12th.
St Paul [1] [2]	29.79	0.00	30.52	26th [3]	28.86	12th.
Kodiak [1]	29.74	−0.01	30.70	19th	28.76	4th.
Midway Island [1]	30.16	+0.04	30.42	1st	29.58	30th.
Honolulu [4]	30.04	−0.02	30.20	10th	29.81	27th.
Juneau [4]	29.84	−0.12	30.75	21st	29.08	12th.
Tatoosh Island [4] [5]	30.04	0.00	30.42	20th	29.64	6th.
San Francisco [4] [5]	29.96	−0.08	30.21	8th	29.43	22d.
San Diego [4] [5]	29.93	−0.03	30.09	4th	29.71	2d.

[1] P. m. only in averages; a. m. and p. m. in extremes.
[2] For 29 days.
[3] And on the 27th.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Cyclones and gales.—There was a considerable improvement in the weather conditions of April over those of March as regards storminess, especially west of the meridian of 180°, in which great area severe gales were much less frequent. Here, as in the preceding month, the roughest weather reported occurred to the westward of the one hundred and sixtieth meridian of east longitude. The severest cyclone of the month lay as a moderate LOW south of Japan on March 31. On April 1, with gathering energy, it lay east of Honshu, and on the 2d and 3d was southeast of the Kuril Islands, at which time it caused strong to whole gales over a large area in all quadrants, with a maximum reported wind force of 11 from the north on the 3d, encountered with snow by the American steamship *Nevada*, near 46° N., 155° E. This was the heaviest gale indicated as occurring along the trans-Pacific routes during the month. The storm moved rapidly east-northeastward and by the 4th, with abated energy, had become amalgamated with the Aleutian cyclone.

The second cyclone of some importance to shipping over the western part of the upper sailing routes was central over the Japan Sea on the 5th, and from this day until the 9th, during its eastward movement, caused fresh to strong gales, with heavy squalls of rain and snow, between Japan and about the meridian of 160° E.

No further days or periods of equivalent storminess occurred within this region, such later gales as were reported being more local and on only the 22d and 25th rising to whole gale force.

Along the upper routes between 170° east longitude and the American coast, gale winds were far less frequent and severe than to the westward, in spite of the frequently disturbed condition of the weather under the influence of the Aleutian cyclone. At most, winds of force 8 or over were reported on not more than two days in any one 5° square, and were usually of local character, on only one occasion attaining to force 10.

Along the California-Hawaiian routes gales were reported on only two days—the 27th and 28th; the former of fresh force; the latter of force 10, from the southeast, near 29° N., 137° W. The causative disturbance originated near the Hawaiian Islands about the 25th. It spread rapidly northward, joined with a depression lying off the California coast, and for the remainder of the month lay spread over a great part of the central and eastern region of the ocean. It had little violence except locally in its extreme southeast.

The only gales reported from the tropics were the northers encountered in the Gulf of Tehuantepec on the 5th to 7th, and on the 22d. The heaviest weather here occurred on the 6th, when winds of force 10 and 11 overspread for a few hours a considerable portion of the Gulf and to the southward for a distance of at least 250 miles below Salina Cruz. On the 22d a "Tehuantepecer" attained a force of 9. The high velocities in both instances were due to extensive anticyclones extending from the lower part of the United States over the Gulf of Mexico.

Winds at Honolulu.—The prevailing wind direction at Honolulu was from the east during April, with a maximum velocity of 26 miles from the same direction on the 4th. Toward the end of the month the winds changed to southwest and west with the existence of the far-spread cyclone to the northward.

Fog.—The change in fog occurrence from that of March was slight, the percentage of days on which it was reported being a trifle higher in some areas remote from land. Near the California coast, between about 35° and 40° N., it was observed on 11 days. Over scattered localities between 45° and 52° N., 130° to 155° W., it was noted on 10 days. Between 30° and 35° N., 145° and 167° E., it occurred on 9 days, similarly scattered. Between Hong Kong and Shanghai reporting vessels found it on three days.

Smoke.—As in March, smoke continued to be observed in April along the Central American and lower Mexican coasts, being actually reported by steamships on 10 days, and as due to brush and forest fires along the hills. It was noted on the 25th along the straits connecting Vancouver Island with the mainland.

Dust at sea.—Owing to the special interest of this occurrence, it is considered in connection with an account of the dust storm in Washington and Oregon April 21–24, 1931, which will appear in a subsequent issue.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5° subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the average temperature for the Caribbean Sea and the Straits of Florida for April of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the April, 1930, means from the 11-year means for April (1920–1930), and the changes from the temperatures for the preceding month of March, 1930.

The chart shows the number of observations taken during the month of April, 1930, within each 1° square; the mean temperature of the Straits of Florida, and of each 5° [1] subdivision of the Caribbean Sea; the 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

During April, temperatures in both the Straits of Florida and the Caribbean Sea continue to possess distinctly cool-season values, the April 11-year means for both areas being intermediate between those for December and January. The trend is, however, distinctly upward, and the last quarter of April is approximately 1° warmer than the same quarter of March in the Caribbean Sea. In the Straits of Florida the temperature difference is nearly 2°.

The surface water was slightly cooler than the 11-year average during the first half of April, 1930 in the Straits of Florida. In the Caribbean Sea, the northwestern portion was somewhat cooler than the average, while the temperature departures were positive over the remainder of the sea with the exception of the eastern extremity, where available data give evidence of cooler water than in March. For the Caribbean as a whole, the departures were small throughout the month.

[1] In 3 cases, as indicated on the chart, the observations from small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5° subdivisions.

TABLE 1.—*Lengths of "Quarter-months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

TABLE 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for April (1919–1930)*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
1919 [1]	43	79.1	14	75.9
1920	155	79.3	34	76.8
1921	179	78.4	46	76.9
1922	194	78.5	74	77.2
1923	389	78.8	109	77.6
1924	342	79.6	109	76.4
1925	251	79.6	101	76.5
1926	302	80.1	110	76.8
1927	313	80.0	128	77.2
1928	435	79.6	152	76.2
1929	495	79.4	126	78.0
1930	580	79.4	127	76.5
Mean (1920–1930)		79.3		76.9

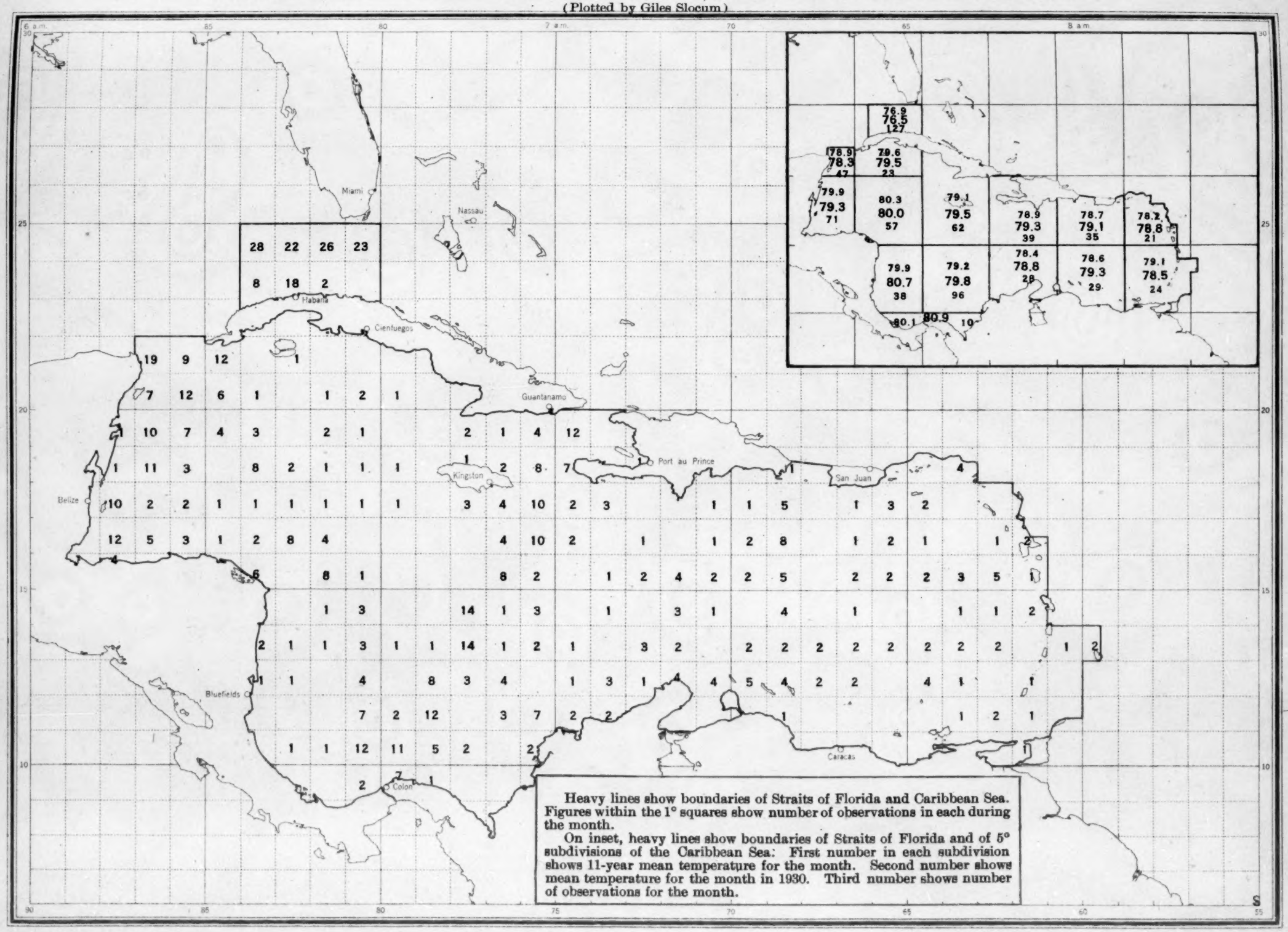
[1] Not used in computations because of insufficient data.

TABLE 3.—*Mean sea-surface temperatures and number of observations, April, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month
			°F.	°F.	°F.		°F.	°F.	°F.
I	Apr. 1 to 7	125	79.3			33	75.5		
II	Apr. 8 to 15	146	79.1			36	76.1		
III	Apr. 16 to 22	140	79.4			37	76.8		
IV	Apr. 23 to 30	169	79.8			21	77.6		
Month		580	79.4	+0.1	+0.5	127	76.5	−0.4	+0.7

Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, April, 1930

(Plotted by Giles Slocum)



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea: First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, April, 1931

[For description of tables and charts, see January, 1931, REVIEW, p. 50]

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	61.5	−2.1	Thomasville	90	17	Valley Head	29	1	3.42	−0.85	Troy (No. 1)	8.66	Tuskegee	1.44
Arizona	62.2	+2.3	2 stations	105	[1] 16	Alpine	14	9	1.09	+0.42	Wikieup	3.88	Goodyear	0.00
Arkansas	59.1	−2.4	Warren	92	18	Dutton	21	6	2.62	−2.43	Little Rock	6.43	Amity	0.62
California	58.6	+3.4	Greenland Ranch	106	22	Ellery Lake	7	25	1.28	−0.43	Squirrel Inn	7.87	Davis	T.
Colorado	44.7	+1.1	Las Animas	92	[1] 8	Dillon	−15	4	1.26	−0.62	North Lake	3.59	2 stations	0.14
Florida	67.5	−2.4	5 stations	90	27	Belle Glade	33	8	4.46	+1.74	Fort Pierce	11.16	Panama City	0.57
Georgia	61.9	−1.6	4 stations	89	[1] 26	Tallapoosa	27	7	3.01	−0.61	Clayton	7.00	Savannah	0.72
Idaho	45.7	+1.0	Lapwai	85	30	Felt	−1	3	0.95	−0.43	Kellogg	3.42	Dubois	0.04
Illinois	53.2	+0.9	Greenville	88	14	Mount Carroll	21	2	2.68	−0.78	Brookport	5.12	Paw Paw	1.41
Indiana	52.5	+0.6	Elliston	89	14	3 stations	21	[1] 2	3.13	−0.43	Boonville	6.04	Winona Lake	1.58
Iowa	50.9	+2.0	Estherville	92	8	Washta	17	1	2.29	−0.67	Bonaparte (near)	5.04	Lake Park (near)	0.82
Kansas	53.1	−1.0	2 stations	90	8	Goodland	20	21	2.41	−0.29	Claflin	4.04	Tribune	0.59
Kentucky	55.9	−0.1	do	89	[1] 16	2 stations	25	[1] 2	4.52	+0.49	Junction City	6.49	Hopkinsville	2.91
Louisiana	63.7	−3.4	Ruston	93	16	Dodson	31	6	2.25	−2.44	Minden	7.75	Lake Charles	0.38
Maryland-Delaware	51.4	−1.0	2 stations	84	9	Oakland, Md	18	30	3.08	−0.49	Oakland, Md	4.52	Coleman, Md	1.95
Michigan	44.4	+1.8	do	86	[1] 10	Deer Park (near)	−2	1	1.49	−1.06	Onaway (near)	4.33	Frankfort	0.17
Minnesota	45.8	+3.2	Beardsley	90	12	Grand Marais	9	5	0.86	−1.13	Grand Meadow	3.05	Crookston	0.05
Mississippi	62.6	−2.0	Eupora	93	15	Port Gibson	32	6	2.41	−2.43	Water Valley	5.70	Natchez	0.42
Missouri	54.8	−0.3	Caruthersville	90	17	Dean	22	5	3.07	−0.74	Downing	6.23	Jefferson City	1.38
Montana	43.9	+1.5	Glasgow	87	17	Adel	−6	3	0.56	−0.58	Red Lodge (near)	3.49	4 stations	T.
Nebraska	50.0	+1.0	2 stations	92	[1] 7	Mullen	10	25	1.38	−1.07	Hebron	4.55	2 stations	0.27
Nevada	50.7	+2.3	Logandale	98	[1] 18	Zorra Vista Ranch	6	3	0.72	−0.04	Lewers Ranch	2.87	Lovelock	0.00
New England	45.6	+1.9	2 stations	86	[1] 19	Garfield, Vt	11	12	2.90	−0.36	Rockport, Mass	5.13	Fort Kent, Me	1.06
New Jersey	49.8	+0.4	3 stations	80	[1] 18	Belleplain	20	30	2.85	−0.91	Woodcliff Lake	5.17	Phillipsburg	1.53
New Mexico	50.5	−0.6	San Marcial	92	19	Dulce	5	2	2.30	+1.32	Gallinas Planting Station.	7.22	San Marcial	0.26
New York	45.9	+1.6	2 stations	86	[1] 21	2 stations	13	6	3.32	+0.35	Boyds Corners	5.31	Chazy	1.02
North Carolina	56.2	−1.7	Newbern	88	9	Mount Mitchell	15	7	4.28	+0.76	Highlands	8.06	Southport	0.93
North Dakota	44.1	+2.5	Max	87	18	Hansboro	3	3	0.43	−0.96	Jamestown	2.38	Minot	0.00
Ohio	50.1	+0.4	2 stations	87	19	Holgate	21	7	4.31	+1.10	Portsmouth (1)	7.76	Montpelier	1.80
Oklahoma	56.7	−3.0	3 stations	88	[1] 14	2 stations	21	[1] 1	3.06	−0.72	Hollis	6.13	Atoka	1.06
Oregon	48.4	+1.6	2 stations	92	21	do	4	18	1.50	−0.47	Mehama	6.15	Frenchglen	0.11
Pennsylvania	48.4	−0.3	do	85	[1] 9	Ridgway	16	24	3.33	−0.11	Lycippus	5.93	Montrose	1.00
South Carolina	60.2	−2.1	Beaufort (near)	89	26	Caesar's Head	29	[1] 2	3.24	+0.16	Caesar's Head	6.93	Charleston	0.92
South Dakota	48.2	+2.5	Forestburg	97	12	Camp Crook	5	23	0.78	−1.32	Harveys Ranch	2.50	2 stations	T.
Tennessee	57.4	−1.3	Cedar Hill	90	16	Rugby	27	7	3.62	−0.86	McGhee	6.56	Memphis	1.27
Texas	61.4	−4.8	Fort McIntosh	97	26	Dalhart	18	1	2.36	−0.80	Boerne	7.09	Denison	0.12
Utah	48.4	+2.0	Leeds	90	19	Soldier Summit	8	3	1.00	−0.35	Silver Lake	3.85	Moab	0.02
Virginia	53.6	−1.0	Christ Church	90	10	Dale Enterprise	22	1	3.55	+0.23	Mendota	5.62	Quantico	2.03
Washington	48.8	+0.8	Wahluke	93	30	Paradise Inn	8	18	2.42	0.00	Forks	13.17	2 stations	0.00
West Virginia	50.7	−1.0	2 stations	88	[1] 14	Bayard	18	30	4.12	+0.48	Dam 19, Ohio River	6.24	Davis	2.13
Wisconsin	46.0	+2.6	do	86	[1] 8	Long Lake	8	11	1.22	−1.36	Mondovi	2.35	Mellen	0.36
Wyoming	40.8	+1.1	Douglas	83	13	Dome Lake	−16	3	1.14	−0.35	Quaking Aspen Creek.	4.26	Eden	0.27
Alaska [March]	15.3	+0.4	Dillingham	60	3	Eagle	−44	14	1.25	−0.62	Ketchikan	11.58	Pilot Station	T.
Hawaii	69.9	−0.1	Pahala	100	27	Kanahuluhulu	42	[1] 9	8.79	−0.19	Puohakamoa (No. 2)	39.40	Waiopai Ranch	0.00
Porto Rico	76.6	+1.3	2 stations	95	17	Guineo Reservoir	51	7	7.25	+2.56	Rio Blanco	17.98	Potala	0.00

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								0–10	*In.*	*In.*
New England							46.7	+2.7										70	2.81	−0.2										4.9		
Eastport	76	67	85	29.87	29.96	+0.03	41.8	+2.8	63	20	49	28	12	35	23	38	32	70	2.31	−0.5	11	7,591	s.	43	e.	1	8	5	17	6.9	1.0	0.0
Greenville, Me	1,070	6	----	28.78	29.96	------	40.7	------	77	20	52	20	12	30	48	------	------	12	5,483	nw.	27	------	13	9	7	14	----	----	9.5	----
Portland, Me	103	82	117	28.87	29.99	+.03	45.6	+2.6	65	19	54	30	12	38	26	39	31	61	3.23	−0.2	11	6,465	nw.	38	s.	26	15	6	9	4.5	4.4	0.0
Concord	289	70	79	29.67	29.98	−.01	46.2	+2.8	79	20	58	26	16	35	45	------	------	------	2.13	−0.6	9	4,796	nw.	28	w.	27	14	10	6	4.0	10.0	0.0
Burlington	403	11	48	29.54	29.98	−.01	45.7	+2.4	78	21	55	25	16	36	37	------	------	------	2.24	+0.1	12	7,019	n.	42	sw.	10	10	8	12	5.8	T.	0.0
Northfield	876	12	60	29.03	30.00	+.01	42.2	+1.9	79	21	54	20	16	30	47	39	36	79	2.27	0.0	10	5,225	s.	28	sw.	11	10	11	9	5.4	1.3	0.0
Boston	125	106	165	29.86	30.00	+.03	50.2	+3.8	78	20	59	32	12	42	30	42	33	57	3.12	−0.2	9	6,006	nw.	27	nw.	27	15	5	10	4.5	T.	0.0
Nantucket	12	14	90	29.98	29.99	+.02	47.0	+3.6	65	21	53	36	8	41	21	43	39	79	3.69	+0.7	11	11,822	sw.	49	ne.	7	15	7	8	4.6	0.0	0.0
Block Island	26	11	46	29.97	30.00	+.02	46.2	+2.2	63	18	52	34	8	40	21	43	40	82	2.48	−1.0	10	11,659	sw.	49	ne.	1	16	6	8	4.5	T.	0.0
Providence	160	215	251	29.82	30.00	+.02	49.7	+3.1	71	21	59	33	12	41	26	43	36	63	2.68	−0.5	10	8,565	nw.	48	nw.	27	15	7	8	4.3	T.	0.0
Hartford	159	122	----	29.83	30.01	+.02	49.6	+2.9	77	21	59	32	12	40	30	------	------	------	2.81	−0.6	11	------	s.	----	----	----	13	8	9	4.9	T.	0.0
New Haven	106	74	153	29.90	30.01	+.02	49.2	+2.0	71	20	58	32	12	41	28	44	40	73	3.98	+0.5	12	7,317	s.	34	ne.	1	13	9	8	4.5	0.0	0.0
Middle Atlantic States							51.5	+0.1										66	2.76	−0.3									5.2		
Albany	97	107	115	29.90	30.01	+.01	49.2	+2.4	80	21	59	31	12	40	37	41	32	57	2.31	−0.2	10	5,455	s.	30	se.	10	14	9	7	4.4	0.5	0.0
Binghamton	871	10	84	29.08	30.03	+.01	46.0	+0.6	78	20	56	26	5	36	42	------	------	------	3.72	+1.2	14	4,681	nw.	26	sw.	26	9	5	16	6.6	3.0	0.0
New York	314	414	454	29.68	30.02	+.02	50.4	+1.0	69	18	58	34	12	43	26	43	36	63	3.30	+0.1	10	11,600	n.	54	nw.	29	10	8	12	5.7	T.	0.0
Bellefonte	1,050	5	36	28.90	30.02	------	45.7	------	76	13	58	24	12	34	47	40	34	67	3.85	------	11	------	sw.	40	sw.	26	11	4	15	6.0	3.9	0.0
Harrisburg	374	94	104	29.64	30.04	+.02	50.9	0.0	76	21	60	35	30	41	31	44	36	61	2.01	−0.7	8	5,380	nw.	32	w.	26	11	8	11	5.0	T.	0.0
Philadelphia	114	123	367	29.91	30.04	+.03	53.2	+1.1	78	19	62	37	12	44	26	44	35	56	2.05	−1.0	8	10,606	sw.	46	ne.	1	11	8	11	5.0	0.0	0.0
Reading	325	81	98	29.67	30.03	------	51.2	+0.9	76	10	61	35	12	42	31	43	35	59	1.91	−1.4	10	5,202	se.	47	e.	1	11	10	9	5.2	0.0	0.0
Scranton	805	111	119	29.15	30.02	+.01	47.5	−0.6	77	20	58	28	12	37	40	41	34	63	2.30	−0.5	12	5,202	sw.	28	ne.	1	11	6	13	5.4	T.	0.0
Atlantic City	52	37	172	29.97	30.03	+.03	49.3	+1.5	67	18	55	37	12	43	24	44	39	72	2.12	−0.9	9	12,911	s.	62	ne.	11	13	7	10	4.4	0.0	0.0
Cape May	17	13	49	----	----	------	49.4	+1.0	69	18	57	33	30	42	25	46	44	85	2.23	−0.8	12	------	se.	----	----	----	12	7	11	----	0.0	0.0
Sandy Hook	22	10	55	29.98	30.00	------	49.6	------	70	18	56	37	12	43	24	44	38	70	2.38	−1.2	10	11,001	w.	50	ne.	1	12	8	10	4.7	0.0	0.0
Trenton	190	159	183	29.82	30.02	------	50.8	+1.0	76	21	61	33	12	41	31	44	38	67	2.07	−0.9	10	8,335	sw.	48	ne.	1	13	6	11	5.0	0.0	0.0
Baltimore	123	100	215	29.89	30.02	+.01	53.8	+0.2	75	17	62	36	7	45	28	46	38	60	2.77	−0.6	7	7,962	sw.	42	w.	26	11	9	10	4.9	T.	0.0
Washington	112	62	85	29.91	30.03	+.01	54.2	+0.9	82	10	64	35	7	44	37	45	36	57	2.87	−0.4	8	5,122	nw.	32	nw.	26	13	7	10	5.0	T.	0.0
Cape Henry	18	8	54	30.01	30.03	------	53.6	−1.0	82	26	61	37	13	46	36	48	45	76	3.49	+0.2	9	9,028	se.	42	ne.	6	13	6	11	4.8	0.0	0.0
Lynchburg	681	153	188	29.28	30.03	+.01	55.0	−2.3	84	14	66	33	3	44	40	48	42	64	3.11	+0.2	10	5,086	nw.	35	nw.	26	14	7	9	5.0	0.0	0.0
Norfolk	91	170	205	29.95	30.05	+.04	56.0	−0.8	82	14	66	36	7	46	36	48	42	68	3.24	0.0	8	9,321	s.	52	w.	26	13	6	11	4.9	0.0	0.0
Richmond	144	11	52	29.89	30.05	+.03	54.4	−2.2	84	14	66	35	8	43	39	49	45	76	3.97	+0.5	10	5,943	s.	36	sw.	22	13	4	13	5.1	0.0	0.0
Wytheville	2,304	49	55	27.65	30.04	+.01	50.8	−1.2	77	14	62	31	2	40	38	44	38	68	3.85	+0.9	14	4,206	w.	25	w.	29	10	8	12	5.6	9.3	0.0
South Atlantic States							60.5	−1.4										69	2.64	−0.4									5.2		
Asheville	2,253	89	104	27.71	30.08	+.05	53.4	−0.5	78	9	65	33	6	42	37	45	39	67	4.71	+1.7	11	5,678	nw.	28	n.	22	11	8	11	5.3	4.3	0.0
Charlotte	779	55	62	29.21	30.05	+.02	58.5	−1.3	82	9	68	37	7	49	31	50	43	64	2.60	−0.7	14	3,756	ne.	20	w.	26	11	3	16	5.8	0.0	0.0
Greensboro	886	6	56	29.10	30.06	------	54.5	------	81	14	66	32	8	43	41	48	43	70	4.28	------	14	5,894	sw.	28	w.	26	8	8	14	6.0	T.	0.0
Hatteras	11	5	50	30.03	30.04	+.03	58.0	−1.8	73	18	65	49	8	51	25	54	50	78	2.71	−0.8	9	8,742	sw.	42	nw.	22	15	6	9	4.9	0.0	0.0
Raleigh	376	103	146	29.64	30.05	+.02	57.4	−2.0	83	9	68	37	7	47	33	50	42	63	3.44	0.0	13	5,892	sw.	31	w.	26	10	7	13	6.0	0.0	0.0
Wilmington	78	81	91	30.00	30.08	+.05	60.6	−1.4	84	9	71	41	7	51	30	54	49	72	1.13	−1.5	8	5,095	sw.	24	sw.	4	12	12	6	4.5	0.0	0.0
Charleston	48	11	92	30.02	30.07	+.04	63.6	−0.9	84	30	71	43	7	56	26	57	53	74	0.92	−1.6	7	7,014	sw.	33	nw.	26	13	7	10	4.5	0.0	0.0
Columbia, S. C	351	41	57	29.68	30.06	+.03	60.8	−2.5	81	30	71	40	7	51	31	52	45	63	2.82	−0.1	11	4,733	e.	30	sw.	26	12	9	9	4.9	0.0	0.0
Due West	711	10	55	29.30	30.08	------	59.2	------	79	30	70	37	7	48	37	------	------	------	1.51	------	12	6,233	sw.	39	w.	26	12	2	16	5.5	0.6	0.0
Greenville, S. C	1,039	139	146	28.95	30.05	------	59.5	+0.9	78	29	69	38	7	50	32	50	42	60	3.63	−0.1	10	6,046	ne.	36	w.	26	11	6	13	5.3	0.0	0.0
Augusta	182	62	77	29.86	30.05	+.02	62.9	−1.3	83	3	74	40	7	52	35	55	51	72	2.92	−0.2	9	3,884	nw.	25	w.	4	12	8	10	4.9	0.0	0.0
Savannah	65	150	194	29.99	30.06	+.03	64.8	−1.2	86	30	74	42	7	55	28	56	52	72	0.72	−1.8	5	8,034	w.	36	w.	1	13	7	10	4.6	0.0	0.0
Jacksonville	43	209	245	30.02	30.07	+.03	65.8	−2.9	85	30	74	46	7	58	27	58	53	72	3.41	+1.0	6	7,552	n.	38	nw.	1	11	9	10	5.0	0.0	0.0
Florida Peninsula							71.3	−1.8										76	5.18	+3.0									5.7		
Key West	22	10	64	29.98	30.00	−.02	73.6	−2.1	84	25	79	59	7	68	17	68	65	77	3.73	+2.4	8	6,954	e.	48	w.	1	8	14	8	5.2	0.0	0.0
Miami	25	124	168	30.00	30.03	−.01	71.3	−1.5	82	27	77	48	7	66	22	66	62	74	4.59	+1.5	15	7,031	e.	30	w.	1	5	9	16	7.1	0.0	0.0
Tampa	35	79	197	30.01	30.05	−.01	69.0	−1.9	86	30	78	52	7	61	25	62	59	77	7.23	+5.2	7	7,794	e.	35	ne.	15	7	13	10	6.0	0.0	0.0
Titusville	44	5	----	30.01	30.06	------	68.9	------	87	26	77	46	7	61	29	------	------	------	2.40	------	4	------	e.	----	----	----	15	11	4	4.4	0.0	0.0
East Gulf States							62.8	−1.9										68	2.50	−1.7									4.9		
Atlanta	1,173	190	198	28.83	30.07	+.04	59.6	−1.4	82	17	69	38	2	50	27	50	42	59	1.83	−1.8	11	6,456	nw.	33	nw.	26	11	7	12	5.5	0.0	0.0
Macon	370	78	87	29.67	30.07	+.04	62.4	−1.5	84	30	74	40	2	51	37	53	46	62	2.02	−1.1	7	4,142	nw.	21	sw.	22	12	5	13	5.4	0.0	0.0
Thomasville	273	49	103	29.77	30.07	+.04	64.8	−1.9	86	30	75	43	7	54	31	56	50	67	1.31	−2.0	7	5,305	nw.	27	sw.	26	9	10	11	5.5	0.0	0.0
Apalachicola	36	11	51	30.03	30.07	------	64.7	------	80	26	72	47	6	58	21	59	55	74	1.17	−1.6	5	5,874	nw.	26	nw.	1	19	5	6	3.5	0.0	0.0
Pensacola	56	149	185	30.02	30.08	+.06	63.8	−2.9	80	16	69	44	1	58	19	58	53	74	1.80	−2.2	2	7,835	s.	35	nw.	1	13	10	7	4.8	0.0	0.0
Anniston	741	9	57	29.29	30.09	+.06	59.8	−0.6	85	17	72	33	7	47	39	------	------	------	2.69	−1.7	11	3,309	nw.	17	nw.	26	13	6	11	5.1	0.0	0.0
Birmingham	700	11	48	29.31	30.08	+.06	61.4	−1.9	86	17	73	36	1	50	33	52	46	65	4.39	−0.4	10	4,349	nw.	28	se.	19	13	9	8	4.8	0.0	0.0
Mobile	57	125	161	30.01	30.07	+.05	64.3	−2.0	85	18	73	45	6	56	27	58	55	80	3.21	−1.4	6	6,257	s.	30	nw.	21	14	7	9	4.4	0.0	0.0
Montgomery	223	100	112	29.83	30.08	+.05	63.4	−1.9	85	17	74	42	1	53	31	54	48	63	3.68	−0.6	10	4,324	s.	20	n.	5	13	6	11	5.0	0.0	0.0
Corinth	469	6	----	----	----	------	60.9	------	89	15	74	35	7	48	40	------	------	------	3.55	------	9	------	se.	----	----	----	11	13	6	----	0.0	0.0
Meridian	375	87	95	29.68	30.07	+.05	61.8	−2.2	87	17	73	38	7	50	36	53	47	65	3.86	−0.9	6	3,662	ne.	21	s.	2	12	11	7	4.7	0.0	0.0
Vicksburg	247	65	73	29.82	30.11	+.11	63.6	−2.0	86	16	74	40	22	53	30	55	50	68	0.67	−4.5	6	4,492	e.	22	s.	2	12	9	9	4.6	0.0	0.0
New Orleans	53	76	84	30.02	30.07	+.07	66.0	−2.8	85	18	74	43	1	58	28	59	54	72	3.39	−1.8	6	4,112	se.	18	ne.	22	13	6	11	5.0	0.0	0.0
West Gulf States							62.6	−3.9										72	3.00	−0.7									5.9		
Shreveport	249	77	93	29.80	30.07	+.10	63.2	−2.6	86	17	73	36	1	53	30	56	52	72	5.26	+0.6	10	3,873	se.	17	s.	2	9	9	12	5.8	0.0	0.0
Bentonville	1,303	11	44	28.69	30.07	+.11	54.8	−2.1	80	16	66	29	5	44	32	------	------	------	4.16	------	10	2,933	s.	18	n.	20	19	4	7	----	0.0	0.0
Fort Smith	457	79	94	29.58	30.06	+.10	59.0	−2.8	82	16	69	35	1	49	33	51	46	69	2.97	−1.0	10	4,792	e.	29	n.	20	13	6	11	4.9	0.0	0.0
Little Rock	357	136	153	29.69	30.07	+.09	60.6	−1.5	85	16	70	38	5	51	31	52	45	62	6.43	+1.2	10	5,203	n.	48	nw.	30	11	4	15	5.5	0.0	0.0
Austin	605	136	148	29.40	30.03	------	63.2	−4.6	87	2	74	39	5	52	37	56	51	71	5.03	+0.7	8	5,386	se.	29	w.	26	6	11	13	6.4	0.0	0.0
Brownsville	57	83	100	29.95	30.01	------	67.6	−6.1	92	3	75	49	6	60	24	62	59	81	0.57	−0.9	9	7,264	se.	31	se.	2	6	12	12	6.2	0.0	0.0
Corpus Christi	20	11	78	30.01	30.03	+.08	66.3	−4.5	79	25	72	48	5	60	28	61	58	81	1.20	−0.6	9	8,394	se.	31	s.	2	3	11	16	7.0	0.0	0.0
Dallas	512	220	227	29.50	30.05	------	61.0	------	84	25	71	37	5	52	31	------	------	------	1.50	−2.8	7	8,075	se.	40	nw.	20	10	11	9	4.7	0.0	0.0
Fort Worth	670	106	114	29.33	30.04	+.10	61.6	−3.4	88	25	72	38	1	52	31	54	48	65	1.97	−2.0	7	5,371	se.	34	e.	29	6	8	16	6.4	0.0	0.0
Galveston	54	106	114	30.02	30.08	+.11	64.4	−4.3	80	17	69	44	1	60	17	60	57	81	2.26	−0.8	6	7,054	se.	29	n.	21	5	11	14	6.3	0.0	0.0
Groesbeck	461	11	56	29.57	30.06	------	61.0	------	82	2	71	36	1	51	34	------	------	------	3.39	−1.2	9	6,961	s.	31	n.	20	6	11	13	6.4	0.0	0.0
Houston	138	292	314	29.91	30.06	------	64.7	−4.6	84	17	73	42	1	57	26	------	------	------	4.54	+1.0	8	8,038	se.	35	n.	21	7	11	12	6.3	0.0	0.0
Palestine	510	64	72	29.54	30.08	+.12	62.0	−4.0	84	17	72	37	1	52	31	55	50	70	3.10	−1.3	11	4,899	s.	23	s.	2	10	9	11	5.3	0.0	0.0
Port Arthur	34	58	66	30.03	30.06	------	65.4	------	83	16	73	40	1	58	23	------	------	------	1.59	−1.4	6	5,129	s.	27	n.	21	10	9	11	5.4	0.0	0.0
San Antonio	693	242	301	29.30	30.02	+.09	64.2	−4.9	88	2	74	42	5	54	36	56	50	67	2.28	−0.9	13	7,501	e.	38	n.	3	5	17	8	5.7	0.0	0.0
Taylor	571	38	51	29.48	30.08	+.13	62.4	−5.1	85	25	74	37	22	51	40	------	------	------	2.91	−0.8	8	5,570	s.	26	s.	2	6	14	10	5.8	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles							0–10	In.	In.
							54.7	−0.1										64	3.43	−0.2										5.2		
Chattanooga	762	190	215	29.25	30.06	+0.03	59.4	−0.9	86	17	70	36	2	49	32	50	42	57	2.53	−2.3	9	5,767	sw.	27	nw.	26	10	9	11	5.7	0.0	0.0
Knoxville	905	102	111	29.00	30.06	+.03	58.4	+0.4	84	17	69	38	1	48	33	49	43	63	4.81	+0.7	11	4,366	sw.	26	sw.	21	10	10	10	5.4	T.	0.0
Memphis	399	76	97	29.64	30.07	+.07	61.3	−0.5	87	16	71	39	1	52	27	52	44	60	1.29	−3.5	9	5,128	s.	26	s.	25	12	10	8	4.4	0.0	0.0
Nashville	546	168	191	29.50	30.09	+.08	58.4	−0.6	84	16	68	38	1	48	30	50	43	62	2.44	−1.7	9	5,921	nw.	28	nw.	1	13	7	10	4.9	0.0	0.0
Lexington	989	193	230	29.01	30.09	+.07	54.0	−0.3	81	19	63	30	2	45	28				4.36	+0.9	9	7,746	sw.	30	nw.	26	16	6	8	4.1	0.2	0.0
Louisville	525	188	234	29.50	30.06	+.05	56.0	−0.4	82	16	66	33	1	47	28	50	45	70	3.85	0.0	12	6,350	n.	33	w.	26	10	9	11	5.3	T.	0.0
Evansville	431	76	116	29.60	30.07	+.07	56.8	+0.1	83	16	66	36	1	48	26	50	44	68	3.10	−0.8	10	5,417	s.	26	sw.	9	10	8	12	5.2	0.0	0.0
Indianapolis	822	194	230	29.16	30.05	+.05	52.7	+0.6	80	16	62	30	2	44	32	44	37	59	3.58	0.0	13	6,513	nw	31	nw.	26	9	10	11	5.5	T.	0.0
Royal Center	736	11	55	29.25	30.06	.....	49.6	.....	79	13	61	26	2	38	36				2.55	−0.5	12	6,332	nw.	33	w.	28	10	9	11	5.7	T.	0.0
Terre Haute	575	96	129	29.44	30.06	.....	54.7	.....	83	16	65	30	2	45	32	47	41	66	2.68	−1.0	14	5,336	n.	25	n.	5	9	10	11	5.5	0.0	0.0
Cincinnati	627	11	51	29.38	30.06	+.05	53.4	+1.0	82	14	63	32	2	44	34	46	40	65	3.93	+0.8	10	4,597	sw.	26	nw.	26	12	8	10	5.0	1.8	0.0
Columbus	822	216	230	29.17	30.05	+.03	51.7	+0.5	81	14	62	31	7	42	34	44	36	62	4.38	+1.5	10	7,215	nw.	51	w.	26	14	4	12	4.8	T.	0.0
Dayton	899	137	173	29.09	30.05	.....	52.4	+0.8	82	14	62	32	7	43	34	44	37	62	4.43	+1.2	10	5,539	ne.	27	nw.	26	13	8	9	5.1	T.	0.0
Elkins	1,947	59	67	28.00	30.08	+.05	47.5	−1.3	77	19	60	25	30	35	43	41	35	69	2.92	−0.7	11	4,026	nw.	28	w.	26	12	5	13	5.7	2.6	0.0
Parkersburg	637	77	82	29.41	30.07	+.04	53.1	−0.3	83	14	64	33	1	42	38	44	37	62	4.39	+1.2	11	3,802	nw.	30	nw.	26	14	4	12	5.1	1.0	0.0
Pittsburgh	842	353	410	29.12	30.04	+.02	50.6	−0.6	80	19	61	32	27	41	34	45	39	70	3.61	+0.7	9	6,867	w.	40	w.	26	12	5	13	5.5	2.7	0.0
Lower Lake Region							47.2	+1.8										64	2.79	+0.3										5.0		
Buffalo	767	247	280	29.16	30.00	−.01	45.2	+2.4	79	20	53	28	30	37	35	40	34	68	2.54	0.0	13	10,055	w.	60	w.	26	10	9	11	5.3	2.4	0.0
Canton	448	10	61	29.48	29.96	.....	45.0	+2.5	82	21	56	24	12	34	35				2.42	+0.2	9	6,799	w.	40	w.	13	10	10	10	5.5	1.7	0.0
Ithaca	836	74	100	29.09	30.01	.....	46.0	+1.0	78	21	56	26	12	36	40	40	33	65	2.48	0.0	12	7,055	nw.	34	s.	10	10	6	14	6.1	4.3	0.0
Oswego	335	71	85	29.63	30.00	−.01	45.2	+1.6	80	20	53	31	1	37	37	39	32	65	2.47	+0.1	14	7,181	w.	31	w.	27	9	8	13	5.9	T.	0.0
Rochester	523	86	102	29.44	30.03	+.02	47.0	+2.1	85	21	56	28	12	38	36	39	31	59	2.10	−0.2	12	6,072	w.	36	w.	28	12	7	11	5.3	T.	0.0
Syracuse	596	65	79	29.38	30.02	+.01	47.4	+3.0	82	21	56	29	12	38	36				3.07	+0.6	15	5,461	s.	27	sw.	26	12	6	12	5.5	1.0	0.0
Erie	714	130	166	29.25	30.03	+.01	46.6	+1.5	81	20	54	30	12	39	35	41	36	70	3.31	+0.6	11	8,640	w.	40	sw.	28	16	6	8	4.3	4.1	0.0
Cleveland	762	267	337	29.20	30.04	+.02	47.4	+1.2	81	9	55	32	2	40	34	41	34	62	3.46	+1.0	12	9,033	w.	49	w.	26	15	5	10	4.7	1.5	0.0
Sandusky	629	5	67	29.36	30.05	+.03	48.7	+1.5	82	20	57	33	28	40	37				4.14	+1.6	10	6,026	e.	34	w.	26	15	4	11	4.7	0.3	0.0
Toledo	628	208	243	29.36	30.05	+.04	49.0	+1.4	79	13	58	30	7	40	35	41	33	60	2.99	+0.3	10	8,246	w.	43	w.	28	18	4	8	3.9	0.3	0.0
Fort Wayne	856	100	119	29.12	30.05	.....	50.0	+0.7	79	13	60	32	28	40	34	43	36	64	2.67	−0.4	12	6,146	nw.	34	nw.	26	16	6	8	4.6	2.1	0.0
Detroit	730	218	258	29.25	30.05	+.03	48.6	+2.4	80	13	59	29	6	38	37	41	34	64	1.87	−0.6	7	6,055	ne.	33	sw.	28	17	5	8	4.0	2.1	0.0
Upper Lake Region							43.6	+2.1										66	1.36	−1.1										5.2		
Alpena	609	13	92	29.36	30.03	+.01	40.7	+2.1	77	12	50	20	6	31	48	36	30	67	1.77	−0.5	8	7,823	nw.	36	nw.	26	11	10	9	4.8	2.6	0.0
Escanaba	612	54	60	29.37	30.05	+.03	39.7	+1.8	60	8	48	22	11	32	29	34	28	66	0.51	−1.7	7	6,701	s.	30	nw.	22	11	9	10	5.3	T.	0.0
Grand Haven	632	54	89	29.35	30.04	+.03	44.2	+0.5	72	15	52	24	6	36	31	38	32	66	1.08	−1.6	8	7,012	sw.	33	nw.	26	11	6	13	5.7	0.1	0.0
Grand Rapids	707	70	244	29.27	30.05	+.03	48.6	+1.6	79	9	59	27	6	38	40	40	31	56	1.75	−1.0	4	7,151	sw.	37	sw.	12	8	10	12	5.7	T.	0.0
Houghton	668	64	99	29.29	30.02	.00	40.2	+2.5	79	18	50	18	5	30	46				1.15	−1.1	8	6,293	e.	38	nw.	10	10	8	12	5.1	5.3	0.0
Lansing	878	6	88	29.08	30.03	.....	47.1	+1.5	80	9	59	24	7	35	46	40	34	66	1.87	−0.7	8	5,934	**nw.**	32	nw.	26	15	2	13	4.9	T.	0.0
Ludington	637	60	66	29.33	30.04	.....	42.6	+0.7	68	14	50	24	6	36	27	38	34	73	1.15	−1.4	8	6,683	n.	30	sw.	20	14	8	8	4.3	T.	0.0
Marquette	734	77	111	29.22	30.03	+.01	41.0	+3.2	80	12	50	22	11	33	47	35	29	65	2.08	−0.4	9	7,177	nw.	43	sw.	12	8	6	16	6.5	10.9	0.0
Port Huron	638	70	120	29.33	30.03	+.01	44.5	+1.5	79	13	54	27	7	35	39	38	33	70	2.28	0.0	8	7,231	n.	37	nw.	26	11	7	12	5.1	0.9	0.0
Sault Sainte Marie	614	11	52	29.33	30.04	+.01	38.5	+1.1	66	18	47	18	1	30	35	34	29	73	1.04	−1.2	8	5,943	nw.	31	nw.	28	14	7	9	4.3	2.7	0.0
Chicago	673	7	131	29.33	30.06	+.06	49.2	+2.3	80	13	58	32	2	41	36	42	35	65	1.75	−1.0	7	6,370	ne.	28	nw.	28	9	12	9	5.3	T.	0.0
Green Bay	617	109	141	29.36	30.02	+.01	45.4	+2.2	78	12	56	26	6	35	41	38	32	65	0.63	−2.0	6	7,405	s.	41	sw.	12	9	6	15	6.1	T.	0.0
Milwaukee	681	125	221	29.30	30.04	+.05	46.6	+2.8	78	12	55	30	23	38	41	39	32	64	0.90	−1.8	7	8,252	n.	37	sw.	12	11	10	9	5.1	T.	0.0
Duluth	1,133	5	47	28.81	30.05	+.04	42.0	+5.0	76	18	53	19	11	31	35	35	28	64	1.04	−1.0	7	7,989	ne.	38	w.	10	15	10	5	4.0	2.7	0.0
North Dakota							44.6	+3.8										54	0.54	−1.2										4.4		
Moorhead	940	50	58	29.00	30.03	+.04	44.6	+4.0	82	17	58	16	4	31	42	36	26	56	0.46	−1.7	5	6,927	n.	28	nw.	8	10	11	9	5.4	T.	0.0
Bismarck	1,674	8	57	28.22	30.02	+.05	45.6	+3.5	83	17	59	17	3	32	43	37	27	56	0.42	−1.1	4	6,299	nw.	35	s.	14	15	13	2	3.7	0.8	0.0
Devils Lake	1,478	11	44	28.42	30.02	+.03	42.4	+3.6	82	17	55	11	3	30	42	35	25	58	0.65	−0.9	5	7,282	n.	28	nw.	8	13	9	8	4.8	1.4	0.0
Ellendale	1,457	10	56	28.46	30.04	.....	44.8	.....	81	17	58	15	4	31	46				1.15	−1.0	6	9,895	nw.	48	nw.	8	9	15	6	5.0	1.7	0.0
Grand Forks	833	12	67	.....	.....	.....	43.6	.....	82	17	58	16	4	29	44	36	.....	.....	0.15	.....	2	.....	nw.	37	w.	8	24	4	2	.....	T.	0.0
Williston	1,878	41	48	28.02	30.02	+.06	46.0	+4.0	82	17	60	18	21	32	42	36	24	47	T.	−1.2	0	5,733	w.	36	nw.	8	15	13	2	3.1	T.	0.0
Upper Mississippi Valley							52.5	+2.3										63	2.08	−0.8										4.9		
Minneapolis	918	102	208	29.00	29.99	.....	50.0	+3.6	83	8	60	28	26	40	34				1.20	−1.0	6	7,949	nw.	37	nw.	10	12	7	11	5.3	T.	0.0
St. Paul	837	114	149	29.12	30.04	+.05	49.6	+4.0	82	12	60	28	26	39	34				1.47	−0.9	7	6,916	n.	44	w.	10	16	5	9	4.6	0.2	0.0
La Crosse	714	11	48	29.25	30.03	+.05	50.2	+3.0	84	8	62	26	2	39	43	41	33	58	1.62	−0.8	9	3,284	nw.	25	sw.	12	13	6	11	4.9	0.3	0.0
Madison	974	70	78	28.98	30.05	+.06	48.0	+2.6	78	13	58	29	6	38	38	40	32	58	1.97	−0.8	7	5,385	nw.	30	sw.	12	13	6	11	4.7	T.	0.0
Wausau	1,247	4	62	28.69	30.04	.....	45.7	.....	78	12	58	23	2	34	41				0.66	−2.0	4	4,391	n.	24	w.	10	18	6	6	3.5	0.2	0.0
Charles City	1,015	10	51	28.97	30.06	+.08	50.0	+3.6	86	8	62	25	1	38	45	41	33	58	1.88	−0.6	8	4,437	nw.	28	sw.	12	16	9	5	3.8	0.0	0.0
Davenport	606	71	79	29.40	30.06	+.08	52.3	+2.4	86	8	62	30	1	42	34	44	36	60	2.71	0.0	9	5,924	w.	34	sw.	12	13	4	13	5.2	T.	0.0
Des Moines	861	5	99	29.15	30.06	+.09	52.2	+2.1	87	8	63	27	1	41	41	44	37	62	1.55	−1.4	9	6,243	nw.	35	s.	12	12	4	14	5.8	0.4	0.0
Dubuque	700	81	96	29.30	30.05	+.07	51.0	+2.4	84	8	61	27	2	41	36	42	34	59	1.43	−1.4	8	3,776	nw.	23	nw.	10	12	5	13	5.0	T.	0.0
Keokuk	614	64	78	29.41	30.08	+.10	53.2	+0.9	81	8	63	31	1	44	32	45	39	65	3.27	+0.3	11	4,345	n.	22	sw.	12	12	5	13	5.4	T.	0.0
Cairo	358	87	93	29.68	30.07	+.08	58.8	+0.7	85	16	68	38	22	50	28	51	46	70	4.00	+0.3	11	5,248	n.	27	nw.	21	10	6	14	5.9	0.0	0.0
Peoria	609	11	45	29.41	30.08	+.09	52.6	+1.7	84	8	63	27	6	42	36	45	39	68	2.23	−1.2	10	3,940	nw.	19	w.	28	15	7	8	4.0	T.	0.0
Springfield, Ill.	636	5	191	29.38	30.06	+.08	54.9	+2.2	83	15	66	31	6	44	36	47	41	68	1.88	−1.6	10	7,214	nw.	29	nw.	26	8	14	8	5.3	T.	0.0
Hannibal	534	74	109	29.50	30.06	+.10	54.4	+1.0	81	8	64	33	1	45	36				2.18	−1.0	9	5,025	nw.	24	sw.	12	13	4	13	5.3	0.0	0.0
St. Louis	568	265	303	29.45	30.06	+.08	57.3	+1.5	84	15	67	35	1	48	36	48	41	62	3.23	−0.6	12	6,889	nw.	28	nw.	21	13	11	6	4.2	T.	0.0
Missouri Valley							52.4	+1.4										58	1.93	−0.9										4.7		
Columbia, Mo.	784	6	84	29.23	30.07	+.09	54.7	−0.2	83	8	64	30	5	45	34				1.42	−2.4	6	4,708	w.	21	sw.	13	11	8	11	5.3	T.	0.0
Kansas City	963	161	181	29.04	30.06	+.12	55.3	+0.5	83	8	64	32	5	46	30	47	40	64	2.62	−0.5	11	5,842	s.	32	n.	20	13	6	11	5.1	T.	0.0
St. Joseph	967	11	49	29.02	30.07	.....	54.2	−1.8	85	8	64	29	5	44	35	46	39	65	3.56	+0.5	9	5,173	sw.	25	nw.	20	15	6	9	4.7	T.	0.0
Springfield, Mo.	1,324	98	104	28.67	30.09	+.12	54.2	+1.8	79	8	63	32	5	46	32	47	40	66	3.80	−0.1	9	5,814	s.	30	nw.	20	19	5	6	3.4	T.	0.0
Iola	984	11	50	29.01	30.07	+.12	54.4	−1.8	81	15	65	28	5	44	35				3.04	−0.4	11	3,754	s.	25	n.	20	12	7	11	5.4	0.0	0.0
Topeka	987	92	107	.....	.....	.....	54.5	−0.2	86	7	65	29	5	44	38				2.49	−0.3	8	5,730	sw.	31	ne.	20	12	9	9	4.6	T.	0.0
Lincoln	1,189	11	81	28.78	30.06	+.12	53.0	+1.5	88	8	64	26	5	42	40	44	37	63	1.76	−0.8	9	6,429	s.	36	nw.	19	8	11	11	5.9	T.	0.0
Omaha	1,105	115	122	28.88	30.07	+.12	53.2	+2.0	88	8	64	27	4	42	39	43	34	57	1.22	−1.3	11	5,074	s.	29	n.	8	14	6	10	4.6	T.	0.0
Valentine	2,598	47	54	27.32	30.07	+.13	48.0	+2.3	88	12	62	21	4	34	44	38	27	55	0.67	−1.2	7	6,050	w.	32	nw.	8	9	14	7	4.8	1.9	0.0
Sioux City	1,135	94	164	28.83	30.05	+.10	51.8	+4.0	89	8	64	26	26	40	41	41	31	53	1.34	−1.4	5	7,984	nw.	41	nw.	8	10	9	11	5.3	T.	0.0
Huron	1,306	59	74	28.64	30.06	+.10	48.8	+3.7	89	12	63	22	3	35	52	39	28	52	1.06	−1.2	5	6,695	s.	35	nw.	8	15	12	3	3.5	0.9	0.0
Pierre	1,572	70	75	28.35	30.03	+.08	49.9	+3.1	85	11	64	24	4	36	43	39	27	48	0.40	−1.4	4	5,897	nw.	38	nw.	8	14	9	7	4.0	0.5	0.0
Yankton	1,233	49	57	28.74	30.07	+.12	51.4	+3.5	86	8	64	26	5	39	44				1.77	−1.0	7	5,006	nw.	32	nw.	8	12	11	7	4.6	0.1	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, April, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								0–10	*In.*	*In.*
Northern Slope							**44.7**	**+1.5**										**52**	**0.99**	**−0.6**										**5.4**		
Billings	3,140	5					45.8		74	30	61	14	3	30	44				0.98		4		nw.				12	8	10		T.	0.0
Havre	2,505	11	67	27.38	30.04	+0.11	46.2	+2.5	81	30	60	16	3	32	42	36	23	50	0.68	−0.3	3	6,647	sw.	36	nw.	19	12	10	8	4.9	0.1	0.0
Helena	4,124	89	113	25.82	30.05	+.08	44.4	+0.9	71	17	57	14	23	32	36	34	21	45	0.25	−0.9	4	6,259	sw.	34	sw.	7	8	10	12	6.1	0.5	0.0
Kalispell	2,973	48	56	26.98	30.06	+.10	44.5	+0.9	76	30	56	21	23	33	38	36	26	55	0.25	−0.6	6	4,483	nw.	32	ne.	21	6	16	8	5.2	1.6	0.0
Miles City	2,371	48	55	27.50	30.08	+.12	48.4	+3.7	82	13	63	16	23	34	42	37	22	42	0.45	−0.7	3	4,694	s.	33	nw.	8	15	9	6	4.2	T.	0.0
Rapid City	3,259	50	58	26.64	30.08	+.13	47.2	+2.9	80	17	59	21	26	35	38	38	26	50	0.36	−1.7	3	5,050	w.	38	nw	8	11	11	8	4.8	0.1	0.0
Cheyenne	6,088	84	101	24.01	30.03	+.12	40.8	−0.1	70	12	52	14	3	29	37	33	23	55	1.72	−0.3	10	7,857	w.	50	nw.	1	7	8	15	6.5	5.6	0.0
Lander	5,372	60	68	24.65	30.03	+.09	43.6	+1.2	72	12	56	19	3	31	39	34	23	51	1.82	−0.2	10	4,080	sw.	36	sw.	13	11	10	9	5.2	15.3	0.0
Sheridan	3,790	10	47	26.12	30.05		43.7		78	17	58	14	4	29	47	35	25	56	2.15	+0.2	7	3,601	nw.	30	nw.	17	6	14	10	5.8	8.8	0.0
Yellowstone Park	6,241	11	48		30.07	+.11	37.8	+0.8	62	12	49	12	3	27	31			53	0.95	−0.5	7	5,787	sw.	26	sw.	7	3	10	17		3.3	0.0
North Platte	2,821	11	51	27.10	30.04	+.12	49.7	+1.1	84	11	62	23	25	37	42	40	31	61	1.25	−0.8	7	4,974	s.	27	nw.	8	9	10	11	5.5	6.5	0.0
Middle Slope							**52.4**	**−1.0**										**62**	**2.81**	**+0.3**										**5.6**		
Denver	5,292	106	113	24.73	30.01	+.11	47.5	+0.4	75	7	58	23	3	37	35	37	25	51	2.23	+0.2	11	4,998	s.	35	ne.	8	7	11	12	5.8	12.5	0.0
Pueblo	4,685	80	86	25.29	29.98	+.10	50.7	+0.6	81	7	65	23	4	37	47	39	26	48	1.02	−0.3	6	4,393	nw.	32	w.	1	9	12	9	5.6	1.8	0.0
Concordia	1,392	50	58	28.60	30.09	+.16	53.2	−0.3	86	8	64	27	5	43	42	46	40	69	3.38	+1.0	11	5,616	s.	25	n.	8	10	9	11	5.5	T.	0.0
Dodge City	2,509	11	51	27.46	30.08	+.18	51.6	−2.0	83	7	63	28	21	40	43	44	39	71	2.10	+0.2	12	8,555	s.	38	n.	8	12	7	11	5.1	T.	0.0
Wichita	1,358	139	158	28.62	30.06	+.13	54.2	−2.2	80	8	64	29	5	45	31	47	41	67	2.49	−0.4	11	7,592	s.	38	sw.	19	10	10	10	5.4	T.	0.0
Broken Arrow	765	11	56	29.25	30.08		56.2		79	7	66	31	5	46	32				4.02	+0.3	10	7,616	se.	41	n.	20	12	5	13	5.5	0.0	0.0
Oklahoma City	1,214	10	47	28.78	30.07	+.15	57.2	−2.6	80	15	68	33	5	47	31	49	43	67	4.45	+1.2	10	5,902	s.	30	n.	20	10	7	13	6.0	0.0	0.0
Southern Slope							**58.7**	**−4.1**										**62**	**2.74**	**+0.9**										**6.2**		
Abilene	1,738	10	52	28.22	30.03	+.13	60.6	−3.8	90	2	72	32	5	49	39	50	43	61	2.15	−0.6	9	6,424	s.	31	n.	20	4	12	14	6.8	0.0	0.0
Amarillo	3,676	10	49	26.29	30.02	+.15	53.8	−2.0	81	7	66	32	21	42	39	44	37	63	1.57	−0.3	10	6,536	s.	26	n.	20	8	10	12	6.2	0.0	0.0
Del Rio	944	64	71	28.98	29.97	+.08	63.8	−6.8	89	25	74	39	5	54	40	56	50	68	2.68	+0.9	10	5,457	se.	33	n.	20	3	19	8	6.1	0.0	0.0
Roswell	3,566	75	85	26.37	29.96	+.11	56.7	−3.9	86	1	69	29	5	44	45	46	36	54	4.54	+3.6	10	5,662	s.	32	se.	8	9	13	8	5.6	0.0	0.0
Southern Plateau							**60.4**	**+3.1**										**45**	**1.22**	**+0.8**										**3.8**		
El Paso	3,778	152	175	26.16	29.91	+.08	62.6	−0.8	87	20	74	39	5	51	38	48	34	43	2.24	+2.0	9	7,621	e.	40	w.	2	16	11	3	3.6	0.0	0.0
Santa Fe	7,013	38	53	23.23	29.92	+.08	47.8	+1.1	70	19	59	27	4	36	31	37	26	51	1.98	+1.0	11	4,154	e.	25	nw.	2	9	9	12	5.6	0.1	0.0
Flagstaff	6,907	10	59	23.32	29.86	+.02	46.0	+3.8	72	20	61	18	9	31	46	37		61	1.49		8	5,413	sw.	30	w.	2	7	12	11		T.	0.0
Phoenix	1,108	10	107	28.70	29.84	−.03	72.4	+5.4	96	20	86	52	9	59	37	54	39	35	0.40	0.0	2	3,757	e.	25	nw.	16	14	13	3	3.5	0.0	0.0
Yuma	141	9	54	29.70	29.84	−.05	73.6	+4.1	101	21	89	53	1	58	43	56	39	37	0.75	+0.6	2	3,035	sw.	25	s.	22	21	4	5	2.6	0.0	0.0
Independence	3,957	6	27	25.91	29.91	+.01	60.2	+5.1	86	19	74	33	24	46	39	43			0.74	+0.6	3		nw.	22	w.	7	19	6	5		0.0	0.0
Middle Plateau							**50.7**	**+2.3**										**42**	**1.08**	**+0.1**										**4.5**		
Reno	4,532	74	81	25.43	29.94	−.03	51.0	+3.7	82	21	66	25	3	36	46	39	27	47	1.35	+0.9	5	3,927	w.	32	w.	1	15	9	6	3.9	12.7	0.0
Tonopah	6,090	12	20				51.2		75	21	62	28	3	41	28	38	23	39	0.75		6		nw.									
Winnemucca	4,344	18	56	25.60	29.98	+.02	49.0	+2.3	77	21	66	21	3	32	49	36	20	38	0.32	−0.5	5	5,160	ne.	30	nw.	21	13	11	6	4.2	T.	0.0
Modena	5,473	10	43	24.57	29.89	+.01	48.4	+2.4	75	18	64	21	3	33	49	37	21	42	0.54	−0.4	4	7,710	w.	51	sw.	22	9	13	8	4.8	T.	0.0
Salt Lake City	4,360	163	203	25.60	29.96	+.04	51.7	+2.1	76	7	62	28	3	41	34	41	28	44	1.84	−0.2	8	5,831	nw.	55	e.	22	14	7	9	4.8	0.1	0.0
Grand Junction	4,602	60	68	25.34	29.90	+.02	53.6	+1.2	78	18	67	27	4	40	39	41	26	42	1.34	+0.5	5	4,365	se.	33	s.	22	10	11	9	5.0	T.	0.0
Northern Plateau							**50.3**	**+0.6**										**50**	**0.57**	**−0.6**										**5.5**		
Baker	3,471	48	53	26.47	30.08	+.08	45.0	−0.2	75	30	58	23	20	32	40	37	29	59	0.61	−0.5	6	4,269	se.	28	nw.	21	11	7	12	5.4	0.7	0.0
Boise	2,739	79	87	27.18	30.05	+.07	50.6	+0.2	76	30	63	29	3	38	36	41	29	48	0.78	−0.4	4	3,780	se.	26	nw.	7	7	8	15	6.0	T.	0.0
Lewiston	757	40	48	29.26	30.07	+.08	53.0	+0.1	84	27	65	31	3	41	39				0.53	−0.6	6	2,665	e.	32	n.	28	10	11	9	5.4	0.0	0.0
Pocatello	4,477	60	68	25.47	30.00	+.06	47.4	+1.4	74	17	59	21	3	36	35	37	25	48	0.88	−0.6	8	5,738	se.	28	sw.	8	12	12	6	5.0	5.2	0.0
Spokane	1,929	101	110	28.01	30.07	+.08	49.3	+0.9	81	30	60	27	3	38	37	40	30	53	0.53	−0.6	8	4,393	sw.	30	ne.	22	9	7	14	6.1	T.	0.0
Walla Walla	991	57	65	28.97	30.05	+.04	53.9	+0.8	83	30	64	35	23	44	30	45	34	50	0.66	−0.8	6	3,666	sw.	24	ne.	22	12	10	8	4.8	0.0	0.0
Yakima	1,076	58	67	28.90	30.06		53.2	+0.7	85	30	66	31	3	41	34	42	28	42	0.02	−0.4	2	4,088	nw.	33	ne.	22	8	13	9	5.7	0.0	0.0
North Pacific Coast Region							**52.6**	**+3.6**										**66**	**2.58**	**−0.3**										**5.6**		
North Head	211	11	56	29.85	30.08	+.03	51.2	+3.7	72	20	56	39	18	46	23	46	42	75	3.21	−0.9	14	9,200	s.	50	s.	6	13	9	8	4.8	0.0	0.0
Port Angeles	29	8	53		30.07		49.2		74	23	57	33	19	41	31				0.85	−0.6	8	4,261	s.	32	w.	16	9	11	10		0.0	0.0
Seattle	125	215	250	29.93	30.06	+.03	52.6	+3.2	78	27	60	37	19	45	29	45	36	59	2.25	−0.1	10	6,049	s.	30	sw.	7	11	10	9	5.3	0.0	0.0
Tacoma	194	172	201	29.84	30.05	+.02	52.1	+3.4	77	27	60	34	19	44	32				2.96	+0.1	10	6,033	s.	43	n.	21	9	12	9	5.3	0.0	0.0
Tatoosh Island	86	9	53	29.94	30.04	+.04	50.1	+4.0	75	23	55	40	1	45	24	47	45	83	6.33	+0.7	15	10,615	s.	45	s.	6	5	10	15	6.5	0.0	0.0
Medford	1,329	29	58	28.59	30.00		54.7		87	21	70	29	2	40	49	45	36	58	1.23	−0.1	6		nw.	36	ne.	22	6	16	8	5.9	0.0	0.0
Portland, Oreg	153	68	106	29.90	30.06	.00	55.6	+3.8	86	27	65	37	18	46	32	47	38	57	2.40	−0.5	10	4,301	nw.	32	ne.	22	7	10	13	6.0	0.0	0.0
Roseburg	510	75	99	29.49	30.04	−.03	54.2	+3.2	83	28	67	33	19	42	45	46	38	62	1.37	−0.9	10	2,869	n.	27	ne.	22	8	15	7	5.1	0.0	0.0
Middle Pacific Coast Region							**59.8**	**+4.1**										**64**	**0.52**	**−1.3**										**4.1**		
Eureka	62	73	89	29.98	30.05	−.06	52.2	+2.3	73	20	59	39	18	45	27	48	45	80	1.61	−1.7	7	4,156	n.	31	ne.	22	13	10	7	4.7	0.0	0.0
Red Bluff	330	5	58	29.58	29.94	−.09	64.6	+5.6	98	21	78	41	3	51	40	51	37	43	0.24	−1.5	3	4,353	nw.	29	n.	22	14	9	7	4.5	0.0	0.0
Sacramento	69	106	117	29.85	29.92	−.09	63.5	+5.4	96	21	77	39	3	50	39	54	46	61	0.05	−1.5	2	4,800	nw.	22	sw.	23	19	10	1	2.6	0.0	0.0
San Francisco	155	208	243	29.80	29.96	−.09	59.0	+4.0	84	20	67	48	10	51	31	51	46	71	0.31	−1.3	3	4,221	w.	25	w.	1	12	9	9	4.6	0.0	0.0
San Jose	141	12	110	29.82	29.97		59.8	+3.1	92	20	74	38	2	46	42				0.40	−0.7	2	3,992	nw.	33	sw.	22	13	9	8	4.0	0.0	0.0
South Pacific Coast Region							**65.3**	**+6.0**										**62**	**1.75**	**+0.8**										**4.5**		
Fresno	327	89	98	29.57	29.92	−.07	66.2	+6.0	96	21	80	44	3	52	38	52	40	47	0.86	−0.1	2	4,951	nw.	28	nw.	1	15	10	5	3.4	0.0	0.0
Los Angeles	338	159	191	29.57	29.94	−.05	66.0	+6.6	89	6	75	52	12	57	29	56	50	64	3.02	+2.0	5	3,127	sw.	17	ne.	26	13	8	9	4.9	0.0	0.0
San Diego	87	62	70	29.84	29.93	−.06	63.8	+5.3	79	6	70	53	4	58	21	58	54	76	1.38	+0.6	5	4,179	sw.	22	s.	26	9	11	10	5.2	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.87	29.96		78.0	+1.4	89	16	83	70	14	73	17				8.29	+3.9	17	7,810	e.	30	ne.	12	1	20	9	6.5	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97		[1]29.81	−.01	83.6	+2.0	95	3	91	73	20	76	19			[1]76	1.45	−1.4	8	6,592	nw.	25	nw.	30		121	8	6.7	0.0	0.0
Cristobal	36	6	97		[1]29.84	−.02	83.2	+1.4	89	30	87	75	18	79	12	77	75	[1]78	4.30	0.0	21	9,013	n.	25	nw.	23		121	8	6.4	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2]29.37	[2]29.91		26.1		57	22	36	−8	2	16	38	22	14	58	0.11		2	3,054	n.	24	ne.	30	9	4	17	6.5	T.	0.0
Juneau	80	11	50	[2]29.75	[2]29.84		43.2		67	24	49	31	1	37	27	39	34	74	7.44		19	4,459	s.	27	se.	5	7	4	19	6.8	5.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2]30.00	[2]30.04		72.4	−0.6	80	18	77	65	20	68	11	65	62	70	0.69	−1.4	15	6,999	e.	26	e.	4	10	16	4	4.3	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, April, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max.+ mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				38.0		45.3	30.7	56	18	6.08		0.0
Sydney, C. B. I.	48	29.91	29.96	+0.07	40.8	+5.8	48.2	33.4	59	22	3.62	−0.23	7.0
Halifax, N. S.	88	29.85	29.96	.00	43.6	+5.8	51.7	35.5	66	27	3.63	−0.55	T.
Yarmouth, N. S.	65	29.85	29.92	−.04	42.6	+3.7	49.1	36.2	63	29	3.82	0.00	T.
Charlottetown, P. E. I.	38	29.85	29.89	−.01	40.0	+4.8	47.0	33.0	58	26	1.88	−0.77	7.6
Chatham, N. B.	28	29.82	29.85	−.05	40.3	+4.8	50.5	30.1	67	20	2.24	−0.39	2.7
Father Point, Que.	20	29.87	29.89	−.04	38.2	+5.0	45.0	31.5	58	24	0.42	−1.16	0.6
Quebec, Que.	296	29.63	29.96	−.03	42.2	+7.1	51.2	33.3	74	23	2.67	+0.58	2.2
Doucet, Que.	1,236				33.9		45.9	21.9	75	−10	1.36		1.9
Montreal, Que.	187	29.73	29.94	−.06	46.5	+6.8	55.6	37.3	79	26	2.82	+0.58	T.
Ottawa, Ont.	236	29.70	29.96	−.06	45.8	+5.8	57.1	34.6	82	24	2.39	+0.89	1.9
Kingston, Ont.	285												
Toronto, Ont.	379	29.60	30.02	.00	44.8	+4.0	53.5	36.1	78	28	1.90	−0.47	2.2
Cochrane, Ont.	930				34.0		44.1	23.9	68	4	3.57		16.2
White River, Ont.	1,244												
London, Ont.	808												
Southampton, Ont.	656	29.29	30.02	−.01	41.1	+2.4	50.3	31.9	72	22	1.91	+0.11	1.0
Parry Sound, Ont.	688	29.31	30.01	−.01	40.3	+2.7	49.0	31.7	75	23	2.38	+0.47	3.6
Port Arthur, Ont.	644	29.29	30.00	−.03	38.4	+4.9	47.4	29.4	65	18	0.77	−0.95	6.2
Winnipeg, Man.	760	29.18	30.03	+.01	41.7	+5.8	52.4	31.0	75	11	0.34	−0.71	1.4
Minnedosa, Man.	1,690	28.17	30.02	+.01	40.3	+4.3	54.2	26.4	81	6	0.15	−0.91	1.2
Le Pas, Man.	860				36.6		48.7	24.5	73	−7	0.20		0.3
Qu'Appelle, Sask.	2,115	27.70	29.96	−.03	42.2	+4.8	55.9	28.4	80	8	T.	−1.05	T.
Moose Jaw, Sask.	1,759				44.6		60.0	29.1	80	12	0.02		0.2
Swift Current, Sask.	2,392	27.41	29.95	−.01	44.0	+2.7	59.1	28.8	77	9	0.24	−0.69	1.6
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.41	30.00	+.02	41.2	+5.1	53.8	28.7	77	9	0.28	−0.55	0.3
Battleford, Sask.	1,592												
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.79	30.05	+.04	51.3	+4.5	58.3	44.4	75	38	1.11	−1.26	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

Late Reports, March, 1931

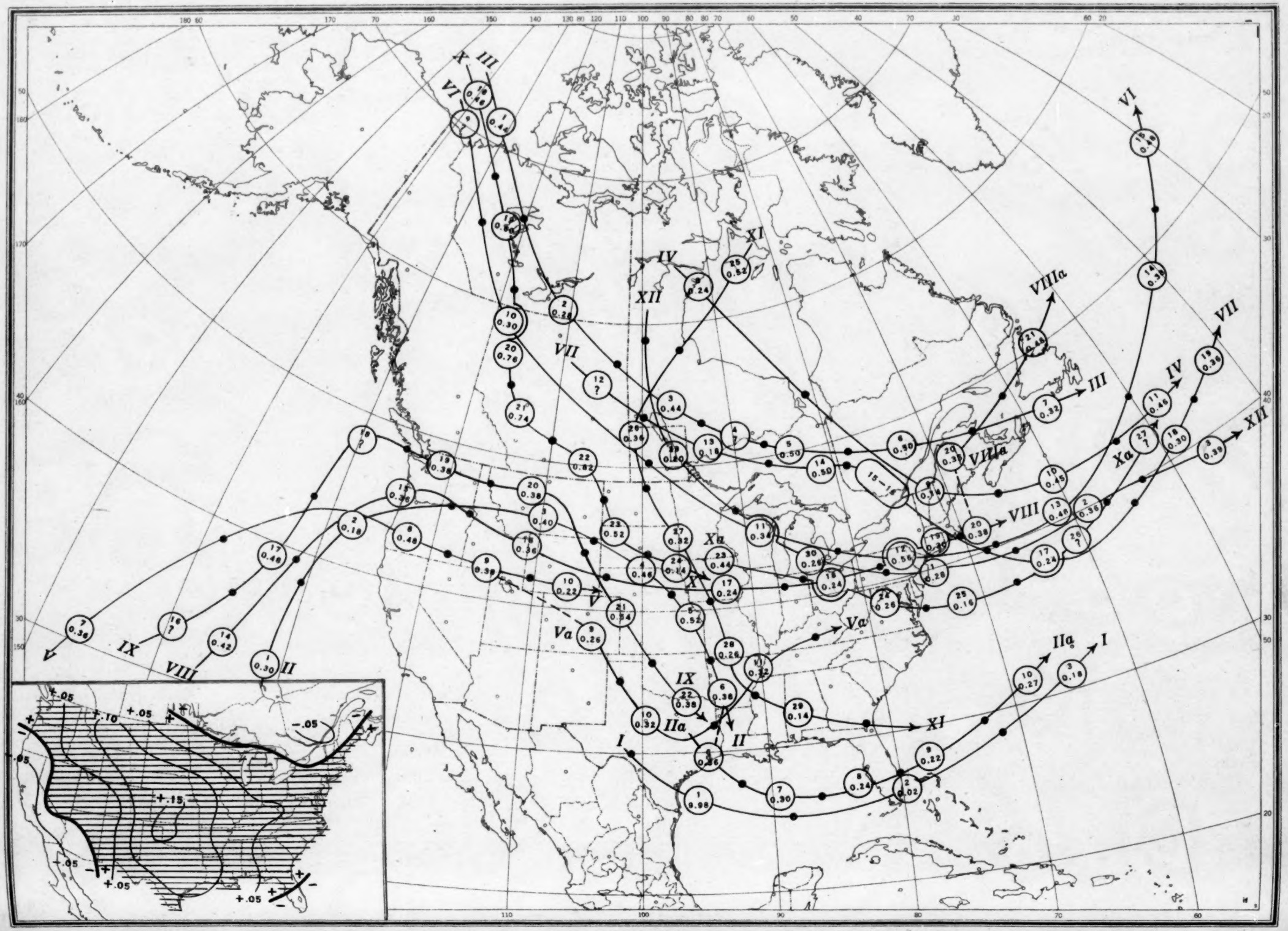
Medicine Hat, Alb.	2,144	27.54	29.84	−.16	31.3	+3.8	42.2	20.4	67	−9	0.52	−0.24	4.6
Banff, Alb.	4,521	25.32	30.02	+.08	26.7	+6.5	36.5	16.9	50	−11	0.80	−0.61	7.4
Edmonton, Alb.	2,150	27.73	30.10	+.14	20.6	−3.6	28.9	12.3	53	−26	1.25	+0.53	12.4

Chart I. Departure (°F.) of the Mean Temperature from the Normal, April, 1931

Chart I. Departure (°F.) of the Mean Temperature from the Normal, April, 1931

Chart II. Tracks of Centers of Anticyclones, April, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by G. E. Dunn)

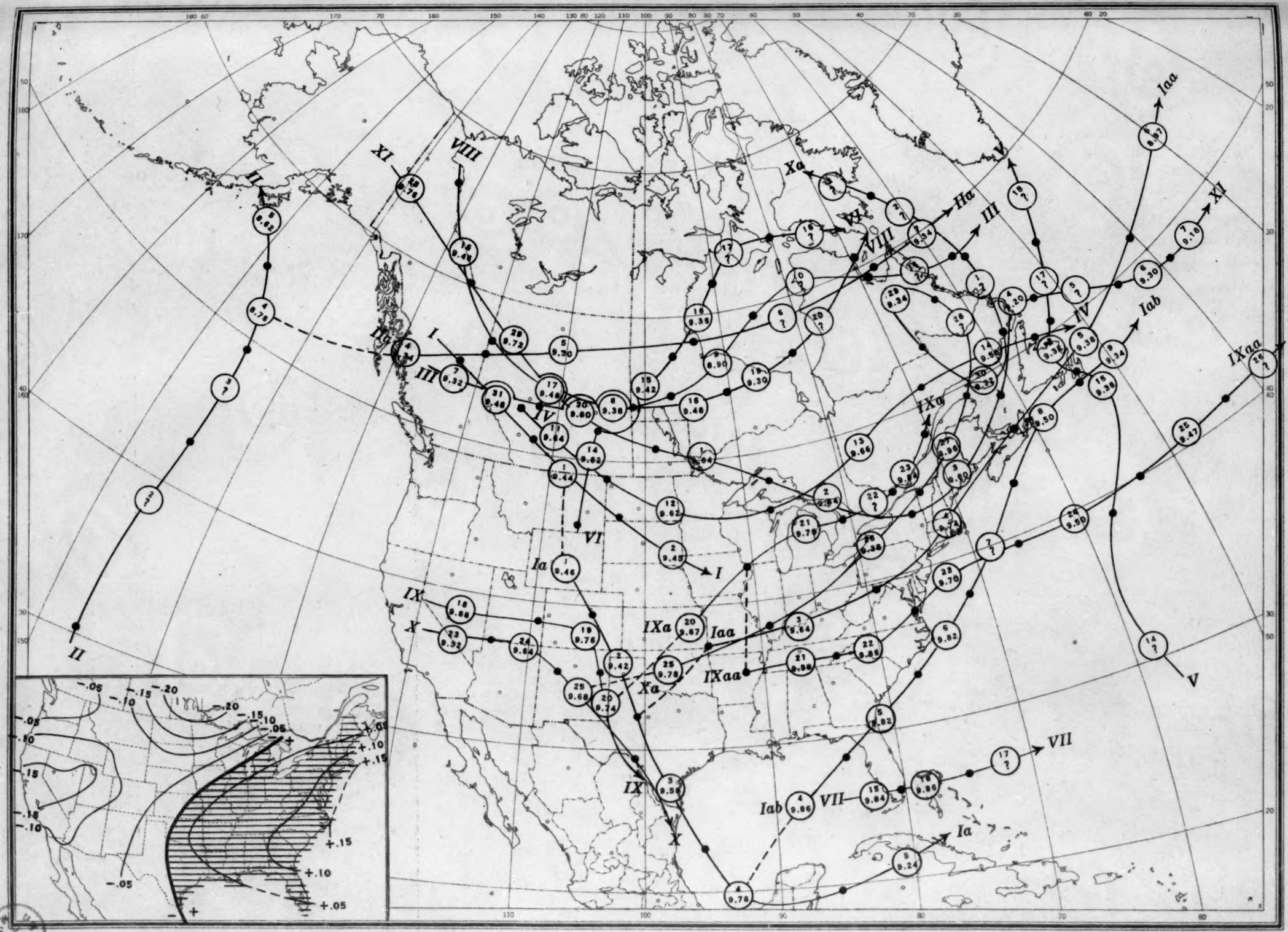


Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

(Plotted by G. E. Dunn)

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, April, 1931

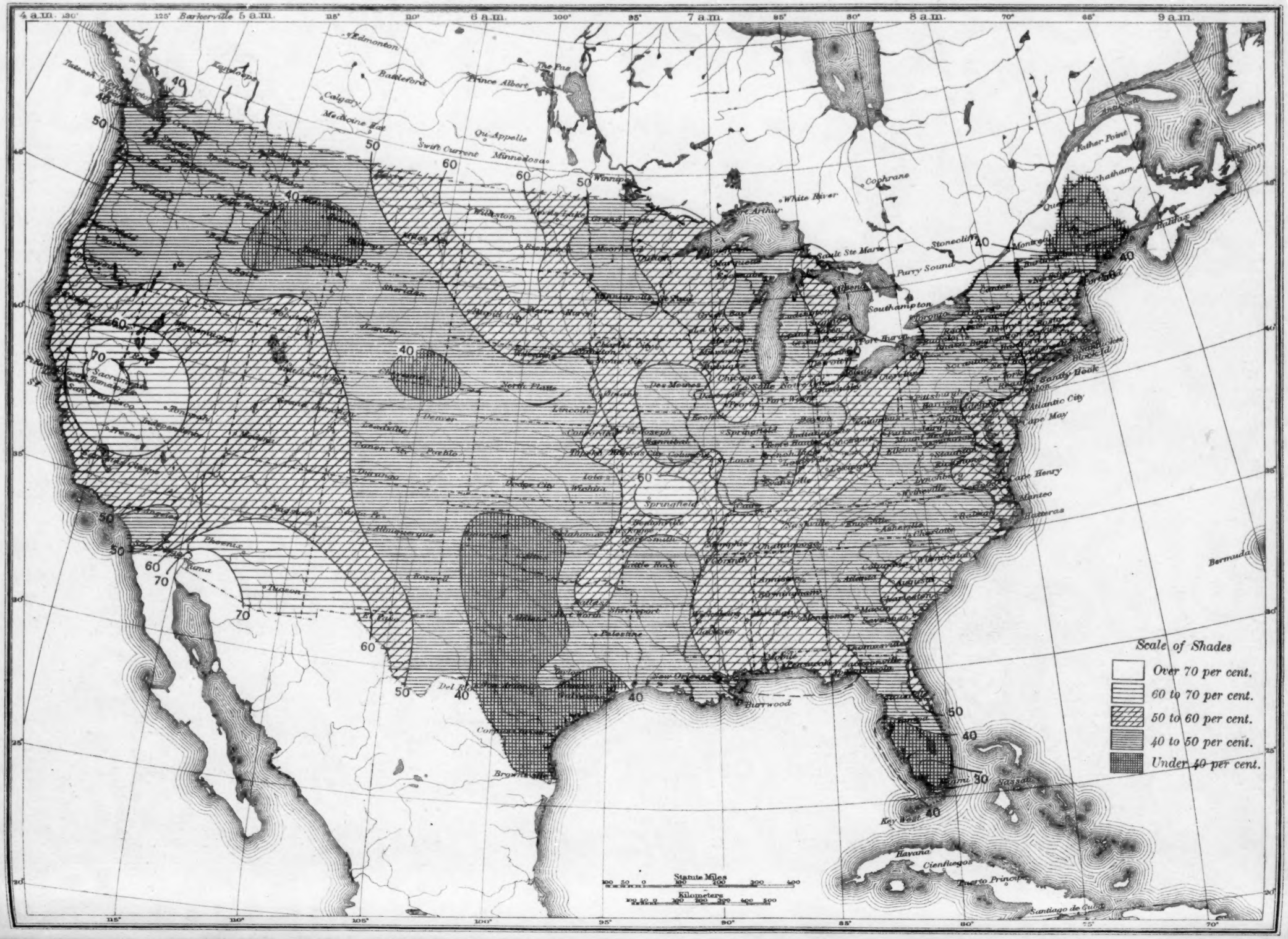


Chart V. Total Precipitation, Inches, April, 1931. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, April, 1931. (Inset) Departure of Precipitation from Normal

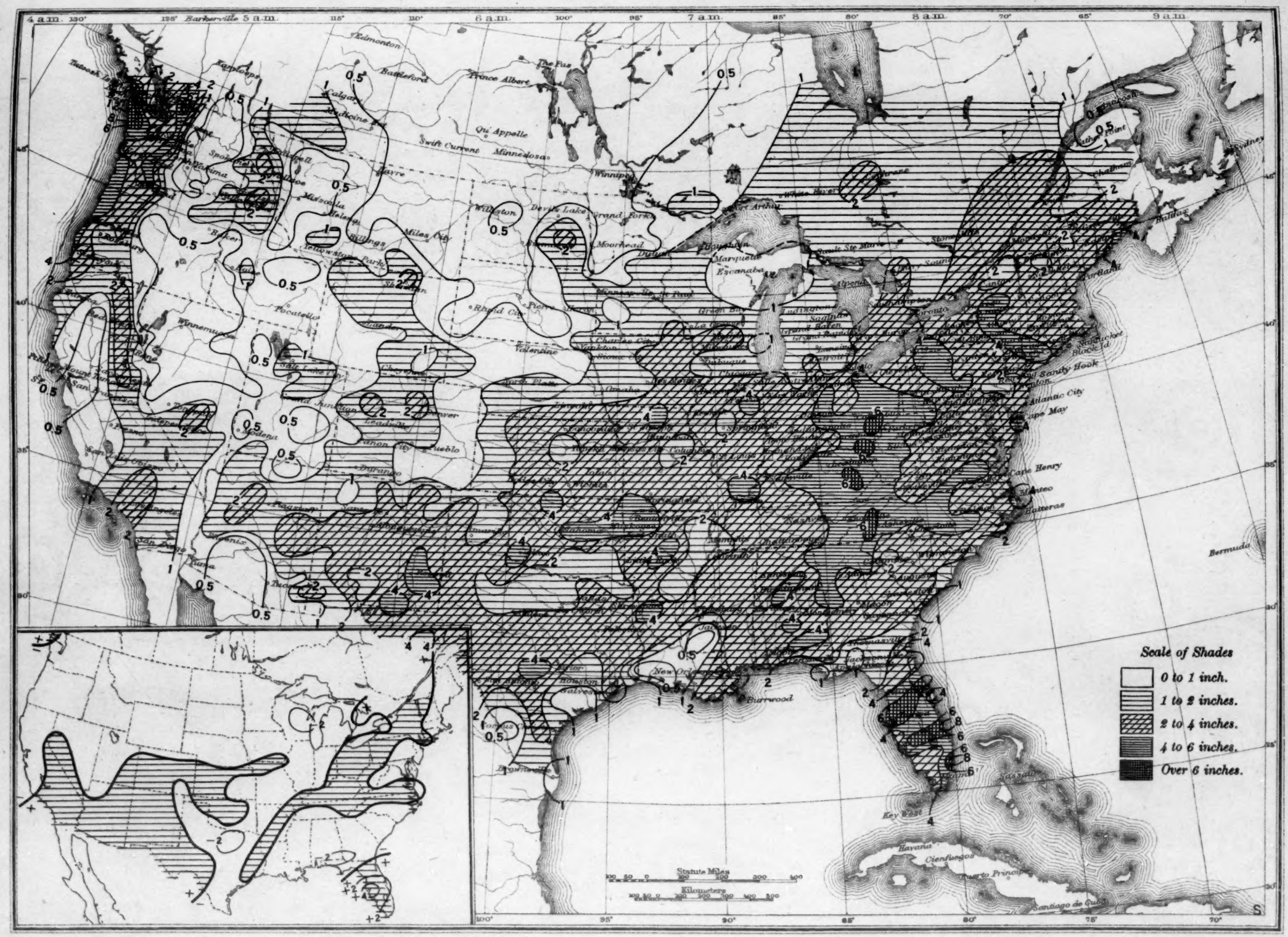


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, April, 1931

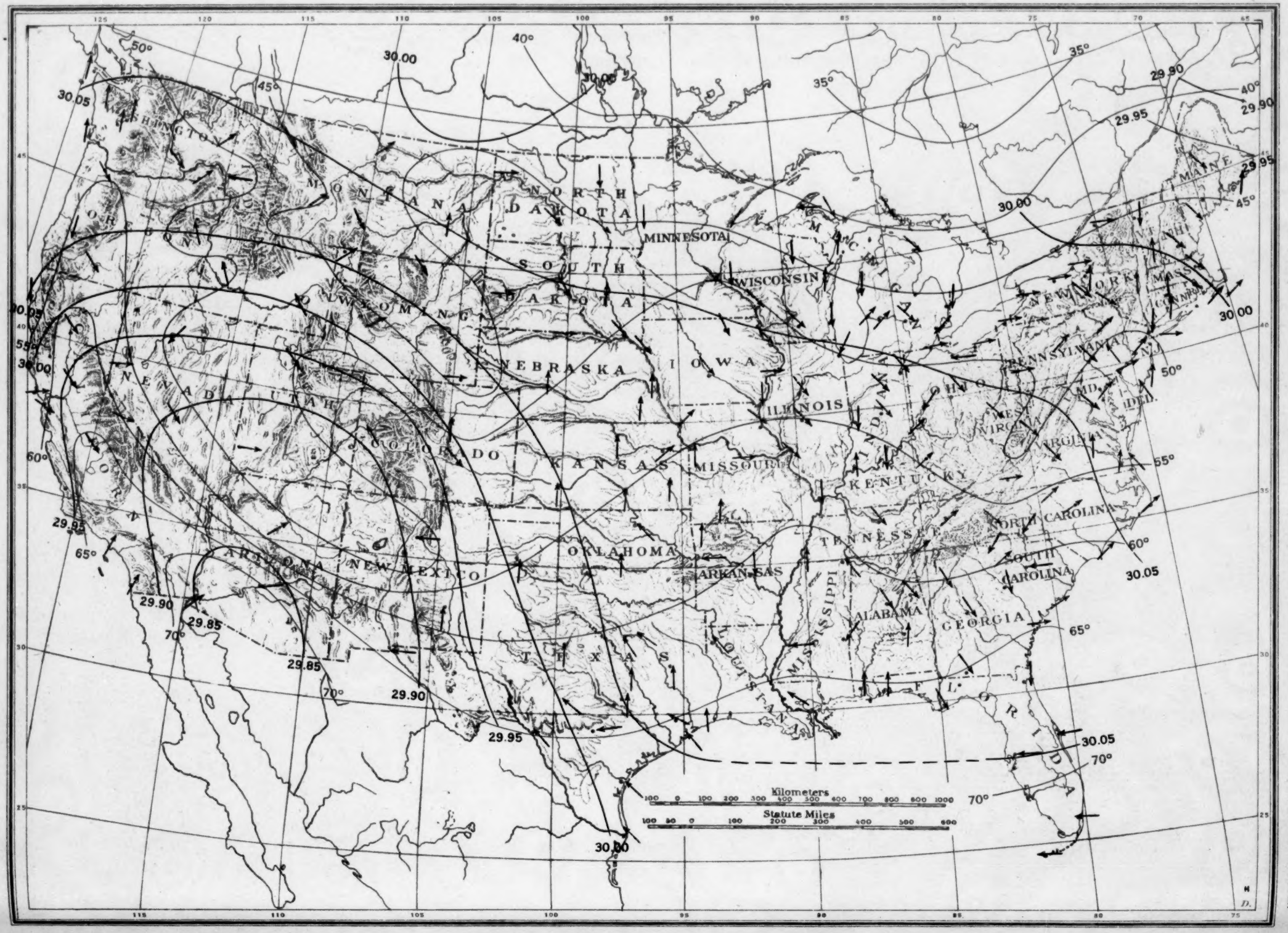


Chart VII. Total Snowfall, Inches, April, 1931.

Chart VII. Total Snowfall, Inches, April, 1931.

April, 1931. M. W. R.

Chart VIII. Weather Map of North Atlantic Ocean, April 1, 1931
(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, April 1, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

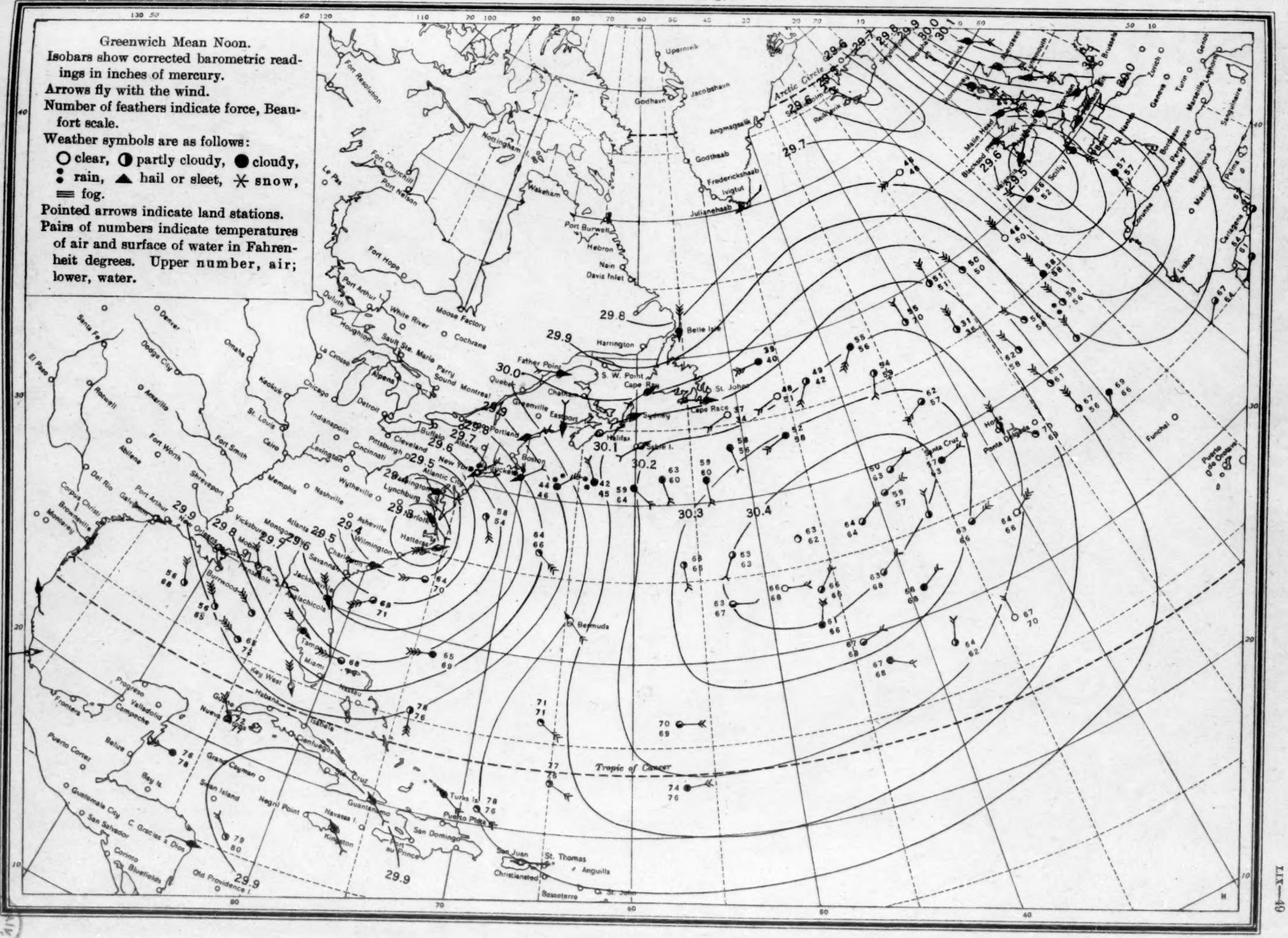


Chart IX. Weather Map of North Atlantic Ocean, April 2, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Tropic of Cancer